Radiation Data and Reports

VOLUME 15, NUMBER 4

APRIL 1974

(Pages 161–226)

RDDRA4 15(4) 161–226 (1974)

UNITED STATES · ENVIRONMENTAL PROTECTION AGENCY

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭ'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
A	ampere(s)	
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps-2.22×10^{12} dpm
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	3.527×10^{-2} ounces= 2.205×10^{-3} pounds
Hz	hertz	cycle per second
kVp	kilovolt peak	
m	meter(s)	39.4 inches=3.28 feet
m^3	cubic meter(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
mi	mile(s)	
ml	milliliter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g
r/min	revolutions per minute	
s	second	
yr	year	

RADIATION DATA AND REPORTS

Volume 15, Number 4, April 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

CONTENTS

CONTENTS—continued

RADIATION DATA AND REPORTS

Published under the direction of

Dr. W. D. Rowe
Deputy Assistant Administrator
for Radiation Programs

Address correspondence to the Editor, *Radiation Data and Reports*, Office of Radiation Programs, HM-561, Waterside Mall East 615, Washington, D.C. 20460.

For subscriptions to *Radiation Data and Reports*, please use the order form on last page of this issue.

U.S. ENVIRONMENTAL PROTECTION AGENCY
Russell E. Train, Administrator

Microwave Hazard Measurements Near Various Aircraft Radars

Richard A. Tell[1] and *John C. Nelson*[2]

In order to determine the potential for exposure of individuals when in the vicinity of aircraft radar units when aircraft are on the ground, the Electromagnetic Radiation Analysis Branch monitored four radar units that were typical of radars used by commercial aircraft. Two of the units were surveyed at a radar simulation laboratory and the other units were surveyed while in their operating positions in aircraft.

The survey determined that the radar beams from navigational and weather radar units in commercial aircraft rotate in either a sector-scanned or 360 degree rotation at approximately 15 r/min. The radar beams emanated from the aircraft above 6 feet from the ground. It was determined that power density exposures of 10 mW/cm² can occur from 8 to 18 feet from the antenna of an aircraft radar unit.

No radiation levels in excess of 0.2 mW/cm² existed in the aircraft cockpits.

This study constitutes part of a continuing effort by the Electromagnetic Radiation Analysis Branch to identify and investigate potential problem areas associated with nonionizing radiation sources in the environment. This effort was aimed at one specific class of microwave emitting equipment—aircraft radar. EPA has an interest in the possible hazards and health implications of all types of nonionizing electromagnetic sources. In this study, the principal concern developed from a desire to know the potential for exposure of individuals when in the close vicinity of aircraft radar units such as when boarding commercial air carriers. The emphasis in this study was not placed on environmental exposure at ground level resulting while aircraft are airborne but rather consists of an examination of possible thermalizing radiation levels near the radars while the aircraft are on the ground.

Data and other pertinent information relating to actual measurements were obtained during a 4-day period (4–7 September 1973) at the Federal Aviation Administration (FAA) Aeronautical Center, Oklahoma City, Okla. During this time, access was provided to a number of the FAA aircraft which are used in training exercises and routine electronic surveillance of air routes in the United States. The radar units in these planes represent a good cross section of the various aircraft radar units used in daily air passenger service in this country and represent normal complements of navigational equipment including weather and navigational radars. Additionally, access was provided to a radar simulation laboratory at which tests could be made on various radars in a test-range environment (rooftop mounted radome with adequate area to make field measurements).

Information relating to typical aircraft radar installations and radar specifications was obtained from the Electromagnetic Compatibility Analysis Center, a Department of Defense installation in Annapolis, Md. which maintains extensive computer files on radiofrequency and microwave equipment.

Objectives

The principal purposes of this study were:

1. to determine the types of radars which are used on board various commercial and private aircraft,
2. to ascertain the pertinent radar specifications which would provide an insight to the potential for hazardous exposure from these units, and
3. to make measurements of radiation levels in the vicinity of several representative radars

[1] U.S. Environmental Protection Agency, Electromagnetic Radiation Analysis Branch, Office of Radiation Programs, 9100 Brookville Road, Silver Spring, Md. 20910.

[2] Current address: Department of Physics, Midwestern University, Wichita Falls, Tex. 76308.

and compare these levels with currently accepted guidelines for safe microwave exposure.

Though the process of theoretically predicting power densities from microwave antennas is an interesting problem, this report does not contain any detailed comparisons of measured data with various analytical approaches because of the complexity of these comparisons. For more information on calculational approaches, particularly of use in the near field, the reader is directed to the appropriate references cited in the text of this report.

Typical aircraft radars

In general, large airplanes used in commercial service (e.g., DC-10, DC-9, B-727, B-707) include at least one radar and sometimes more as a part of their minimal electronic equipment. The primary radar unit normally is used for weather determination, navigation, and general search operations. These radar units are moderately powered, usually in the range of 20 to 100 kW peak power, and, as a rule, have a radar antenna which consists of a parabolic dish mounted in the very front of the aircraft. Many other radiofrequency and microwave sources are found in these aircraft, e.g., altimeters, which commonly use frequency modulated emission, pulsed sources for interrogating ground-based navigational aids such as tacan[3] units, and communications equipment. The airborne radars, however, represent the most powerful of all such equipment found aboard these vehicles and thus present the greatest potential for harmful exposure to nonaircraft personnel if care is not exercised during the operation of the equipment. A summary of radar transmitter characteristics for units found in typical airplanes in use at this time is given in table 1. This table is not intended to be exhaustive but

[3] Tacan is a condensation of tactical air navigation, a complete ultrahigh frequency polar coordinate navigation system using pulse techniques.

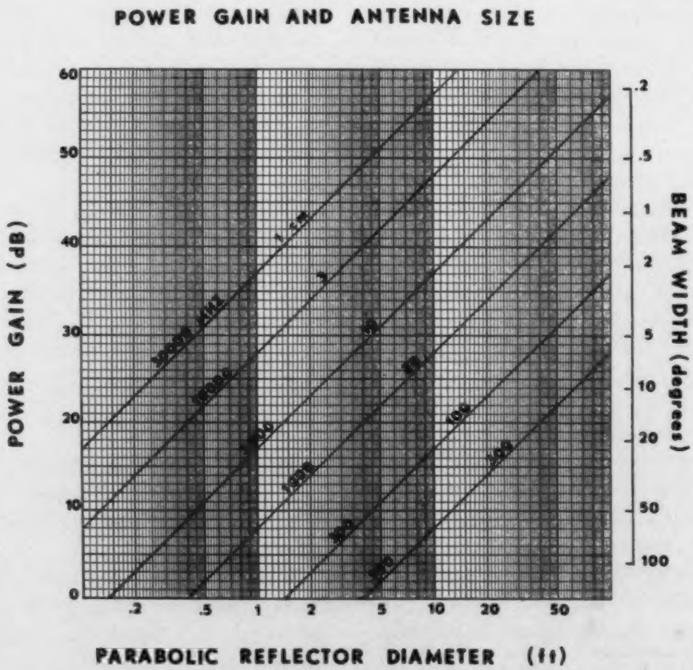


Figure 1. Relationship of dish diameter, gain, and beamwidth for selected frequencies

Table 1. Typical airborne radar specifications

Manufacturer	Model	Frequency range (MHz)	Peak power (kW)	Antenna gain (dB) [a]	Average power (W) [b]
Bendix	RDR-1A	9345-9405	17	29.5	16
	RDR-1B	9307-9405	40	31.0	25
	RDR-1B2	9345-9405	40	31.0	25
	RDR-1C	5370-5430	100	30.0	80
	RDR-1D	9345-9405	17	29.5	16
	RDR-1E	9345-9405	65	37.1	65
	RDR-1F	9300-9500	65	31.0	80
RCA	AVQ-10	5380-5420	75	28.0	60
	AVQ-20	9335-9415	20	27.5	16
	AVQ-30C	5370-5430	60	30.0	122
	AVQ-30X	9315-9375	60	26.0	69
Collins	WP-101	5370-5430	75	33.0	66

[a] The antenna gains listed here are those for a parabolic antenna dish in a typical radar configuration. Manufacturers normally offer more than one size dish for their transmitter, and thus the gain may vary slightly from one installation to another.

[b] The average power from any particular radar system may have several different values depending on the exact pulse width and pulse repetition frequency (PRF) selected. This column lists the highest of the average powers if more than one is possible.

rather indicative of the specifications of typical airborne radars used aboard large aircraft.

As noted in the table, the antenna gain may vary, depending on the actual antenna size employed. The gain of a parabolic dish is a function of its diameter. Figure 1 illustrates the relationship between dish diameter, gain, and beamwidth for several different frequencies. Gain of a well-designed horn-fed parabolic reflector may be estimated from the relationship (*1*):

$$G = 27\,000/(\theta_H \cdot \theta_E)$$

where:

G = absolute gain above an isotropic radiator,

θ_H = 3 dB beamwidth (in degrees) in the H plane of the antenna,

θ_E = 3 dB beamwidth (in degrees) in the E plane of the antenna.

Radar antenna patterns may be shaped differently. The two most commonly used shapes are a narrow "pencil" beam in which the beam is made as narrow as the dish allows, and a cosecant-squared shape applied to the vertical pattern. A cosecant-squared shape refers to the proportionality in the vertical plane of antenna gain to the cosecant squared of the elevation angle. Such a vertical pattern in practical antennas varies as cosecant squared from about the upper 3 dB point to approximately 40 degrees in elevation. Using a vertical cosecant squared radiation pattern allows constant power density illumination of a target as long as the target maintains a constant altitude.

For purposes of estimating the radiation exposure level from a radar, it is necessary, as a minimum, to know the effective radiated power (ERP) from the antenna. This ERP is a measure of the antenna's focusing power and is equal to the product of antenna input power and antenna gain. At distances on the order of $2D^2/\lambda$ or greater (D is the largest dimension of the antenna, the diagonal for rectangular units, and λ is the free space wavelength of the transmitted wave). The power density (for hazard purposes) may be computed from:

$$W = \frac{PG}{4\pi R^2}$$

where,

W = power density at a distance R from the antenna,

P = power available to antenna (taking into account transmission lone losses), and

G = absolute mainbeam gain of the antenna.

This equation is valid only for points on the axis of the mainbeam of the antenna and at distances which are in the far field. For computations of power density at points within the near field, more complicated techniques are required—in this case, the antenna gain must be corrected for application at near field distances. Though exact formulas are difficult to arrive at, the Army has developed some simple equations for use in the near field of circular parabolic antennas on the basis of empirical

data (*2*). Other discussions of near field corrections may be found in the literature (*3,4*).

The power densities computed from any of the equations will be peak or average values depending on the power term entered in the equation. Currently, for hazard purposes, the average power to the antenna is taken as the power which is proportional to the tissue heating effectiveness of the radiation exposure. Peak power densities, especially from pulsed sources such as radars, may be important in various device interferences (*5*). For practical purposes in radar computations, in lieu of actual power measurements, the average power of a transmitter (P_{avg}) is taken as

$$P_{avg} = P_{peak} \cdot PRF \cdot \tau$$

where:

P_{peak} = the peak pulse power (in watts) of the radar transmitter (this is almost always the stated power of radar),

PRF = the pulse repetition frequency (hertz),

τ = the pulse width (seconds).

Figure 2 plots the relation between peak and average power for various PRF's and pulse widths.

Radars and facilities available for test

This section describes the radar units which were surveyed and circumstances under which the measurements were made. It was the intent of the authors to obtain measurement data on several different, but typical, radar types in common use. Under the constraints of the time available, the poor weather conditions, and other measurement projects being conducted during the trip, a total of four radars were surveyed which represent three different models and manufacturers. Prior to making measurements around the radar units mounted in the airplane nose cones, a series of measurements were obtained on similar radars at the radar simulation laboratory. At the simulation facility, actual radars could be operated at will in a relatively controlled environment. Figure 3 depicts the interior of the simulation lab, show-

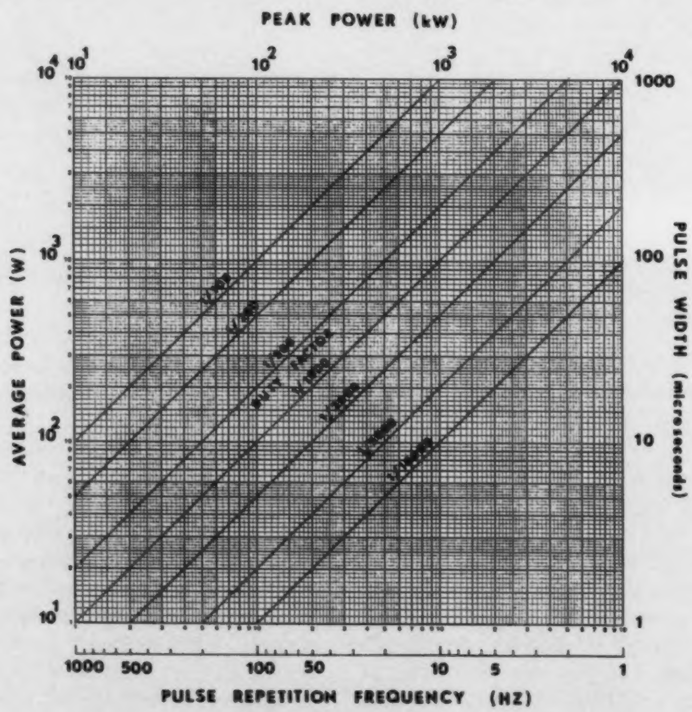


Figure 2. Relationship of peak and average power

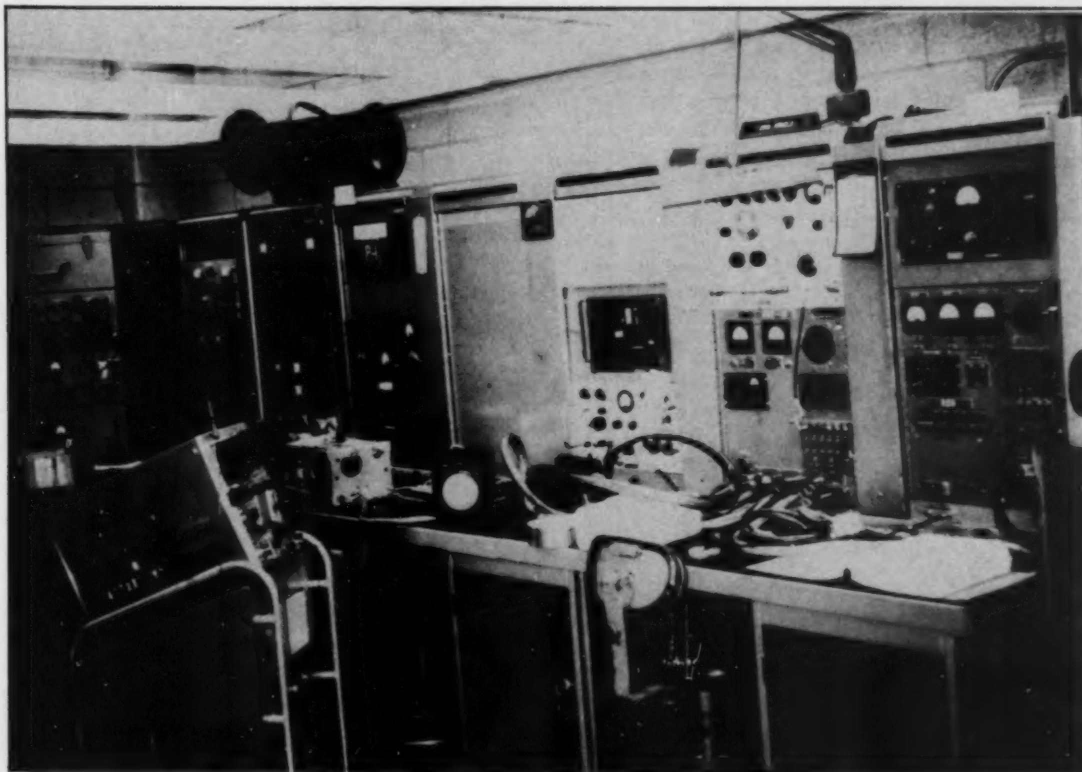


Figure 3. Interior of simulation laboratory

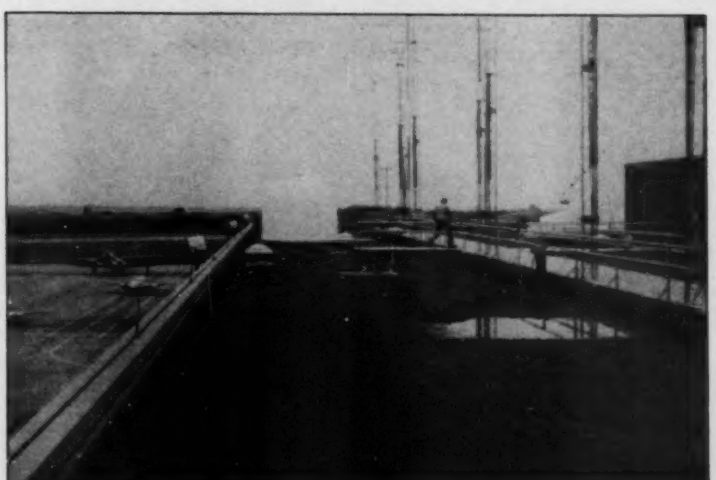


Figure 4. Roof-mounted radome

ing the various power supplies, test equipment, and radar control panels. The actual transmitter unit and antenna were placed on a platform which could be elevated into a radome structure on the roof above the laboratory (figure 4). Notice the large number of communication antennas in the near vicinity. A closeup view of a typical airborne radar dish antenna is shown in figure 5.

Table 2 lists the radars which were measured and their installation configurations. Detailed specifications for each of these radars may be found in tables 3, 4, and 5. The Bendix RDR-1B is capable of two different pulse widths and these are indicated in the table. Also given in these tables are the calculated values for $2D^2/\lambda$, the far-field distance as computed from reference (*2*) ($D^2/2.83\lambda$), the maximum power density expected in the near-field region based on reference (*3*), and the distance to the point where the field is expected to be 10 mW/cm^2, assuming a far-field gain for the specific antenna. The gain of an antenna is always a far-field gain unless otherwise stated (i.e., the gain of an antenna is always that gain which is effective at a distance where the power density decreases as inverse square distance).

Table 2. Summary of radars used in measurements

Radar	Manufacturer	Simulation laboratory	Aircraft
AVQ-10	RCA	X	X
RDR-1B	Bendix	X	
WP-103	Collins		X

The two aircraft radar units surveyed were both installed in the nose cones of their respective planes—a Sabre Liner with the Collins WP-103 and a Convair 600 with the RCA AVQ-10. Figures 6 and 7 show these aircraft parked in the flight operations area of the FAA

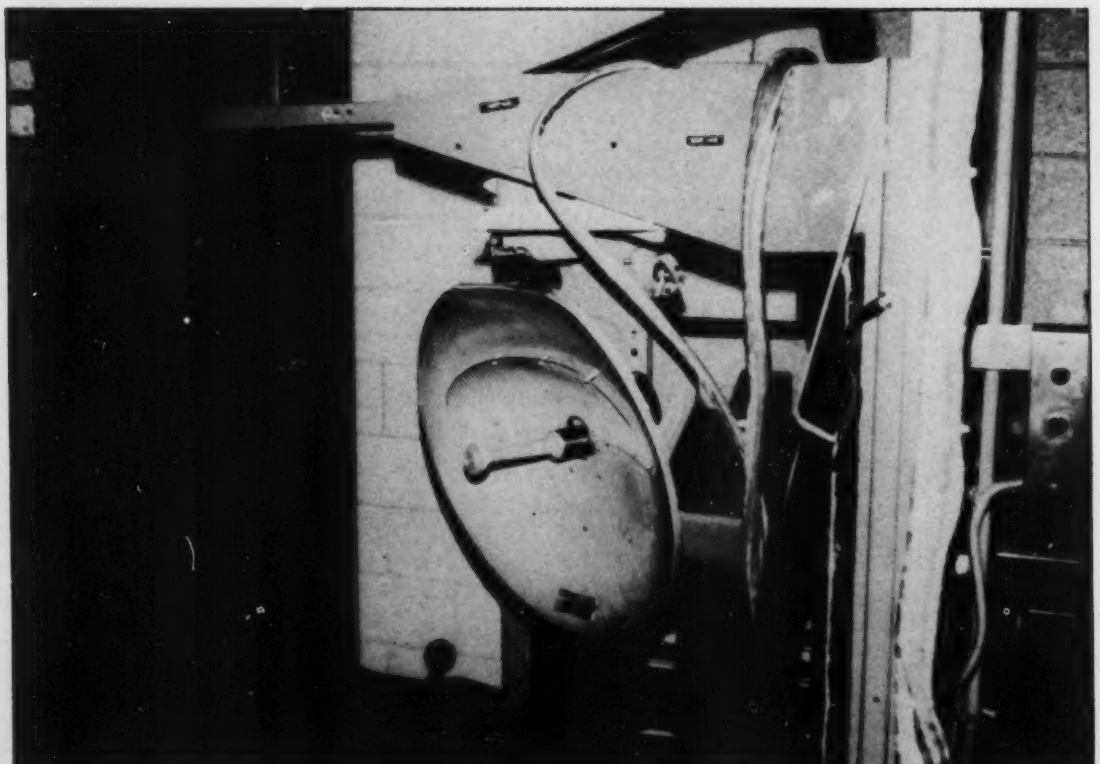


Figure 5. Typical airborne radar dish

Table 3. Specifications for RCA AVQ-10 aircraft radar

Antenna diameter	22 inches	
Transmitting frequency	5400±20 MHz	
Wavelength	5.55 cm	
Pulse width	2 μs	
Pulse repetition frequency	400 Hz	
Duty factor	0.0008	
1/duty factor	1250	
Peak power output	75 kW	
Average power output	60 W	
Antenna gain	33 dB	
Maximum average effective radiated power	120 kW	
Antenna scan angle	360°	
Antenna tilt limits	10° up−15° down	
Antenna rotation speed	15 r/min	
3 dB beam width:	Horizontal	Vertical
Pencil beam	4.5°	4.5°
CSC^2 beam	4.5°	(a)
Polarization:		
Pencil beam	Horizontal	
CSC^2 beam	(a)	
Calculated data:		
$2D^2/\lambda$	11 m (36 feet)	
Distance to beginning of far field ($D^2/2.83\lambda$)	2.0 m (6.6 feet)	
Maximum peak power density in near field	120 W/cm²	
Maximum average power density in near field	100 mW/cm²	
Distance to 10 mW/cm² assuming far field gain	10 m (33 feet)	

a Information not available.

Table 4. Specifications for Bendix RDR-1B aircraft radar

Antenna diameter	22 inches	
Transmitting frequency	9375±30 MHz	
Wavelength	3.20 cm	
Pulse width	1.5 μs search; 2.25 μs beacon	
Pulse repetition frequency	400 Hz	
Duty factor	0.0006; 0.0009	
1/duty factor	1667; 1111	
Peak power output	40 kW	
Average power output	24 W; 36 W	
Antenna gain	30.0 dB	
Maximum average effective radiated power	24 kW; 36 kW	
Antenna scan angle	360°	
Antenna tilt limits	15° up−15° down	
Antenna rotation speed	15 ± 3 r/min	
3 dB beam width:	Horizontal	Vertical
Pencil beam	3.8°	3.8°
CSC^2 beam	3.8°	(a)
Polarization:		
Pencil beam	Horizontal	
CSC^2 beam	Vertical	
Calculated data:		
$2D^2/\lambda$	20 m (66 feet)	
Distance to beginning of far field ($D^2/2.83\lambda$)	3.5 m (11 feet)	
Maximum peak power density in near field	65 W/cm²	
Maximum average power density in near field	39 mW/cm² (at 24 kW ERP); 59 mW/cm² (at 36 kW ERP)	
Distance to 10 mW/cm² assuming far field gain	4.4 m (14 feet) (at 24 kW ERP); 5.4 m (18 feet) (at 36 kW ERP)	

a Information not available.

center. Careful examination of figure 7 reveals the nearby control towers and weather radar at Will Rogers Airport.

Survey equipment

All measurements of radiation levels covered by this report were made with a Narda Microwave Corporation Model 8300 broadband isotropic radiation monitor. This monitor consisted of a Model 8321 isotropic probe (rated for a maximum time average power density of 20 mW/cm² for pulsed fields), and a Model 8310 probe readout meter. Salient characteristics of this device are given in table 6. This particular device, Serial Number 02006, was certified as being calibrated 18 June 1973, or approximately 2.5 months prior to the field trip.

Table 5. Specifications for Collins WP-103 aircraft radar

Antenna diameter	12 inches	
Transmitting frequency	9375 ±40 MHz	
Wavelength	3.20 cm	
Pulse width	2.3 μs nominal	
Pulse repetition frequency	400 Hz	
Duty factor	0.0008 – 0.001	
1/Duty factor	1000 (assuming 0.001 DF)	
Peak power output	20 kW	
Average power output	20 W (assuming 0.001 DF)	
Antenna gain	26 dB	
Maximum average effective radiated power	8 kW	
Antenna scan angle	120° sector	
Antenna tilt limits	12° up – 12° down	
Antenna rotation speed	15 r/min	
3 dB beam width:	Horizontal	Vertical
Pencil beam	(a)	(a)
CSC^2 beam	(a)	(a)
Polarization:		
Pencil beam	Horizontal	
CSC^2 beam	(a)	
Calculated data:		
$2\ D^2/\lambda$	5.8 m (19 feet)	
Distance to beginning of far field ($D^2/2.83\lambda$)	1.0 m (3.4 feet)	
Maximum peak power density in near field	110 W/cm^2	
Maximum average power density in near field	110 mW/cm^2	
Distance to 10 mW/cm^2 assuming far field Gain	2.5 m (8.3 feet)	

[a] Information not available.

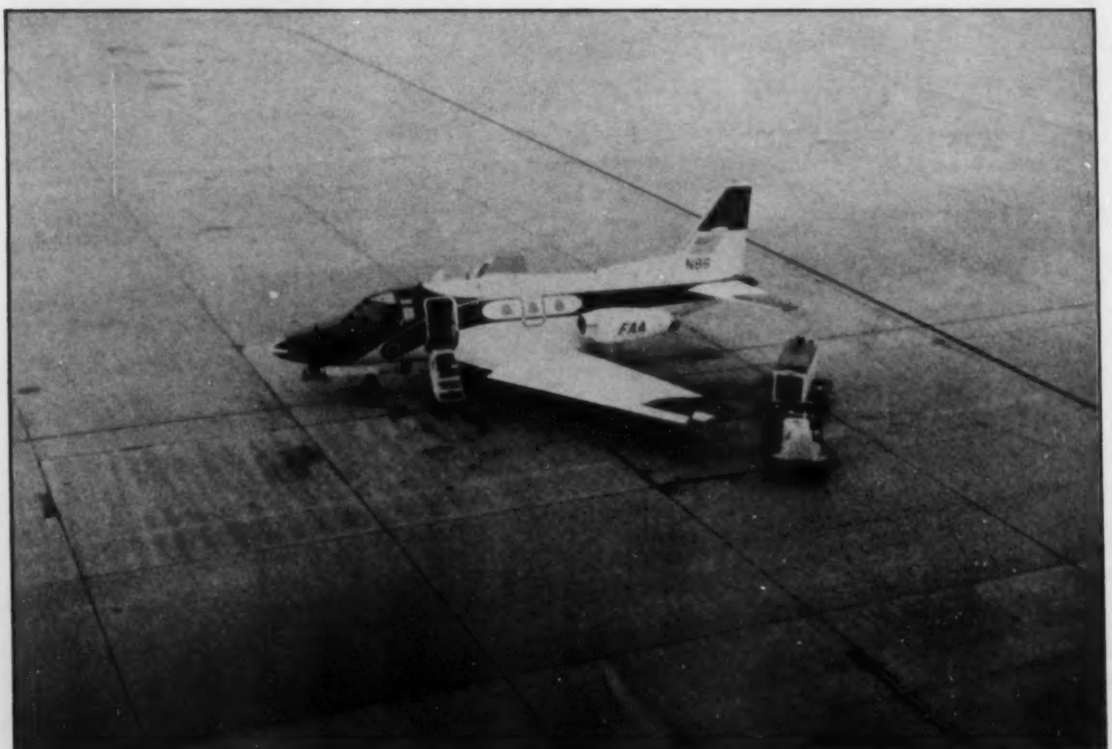


Figure 6. Sabre Liner

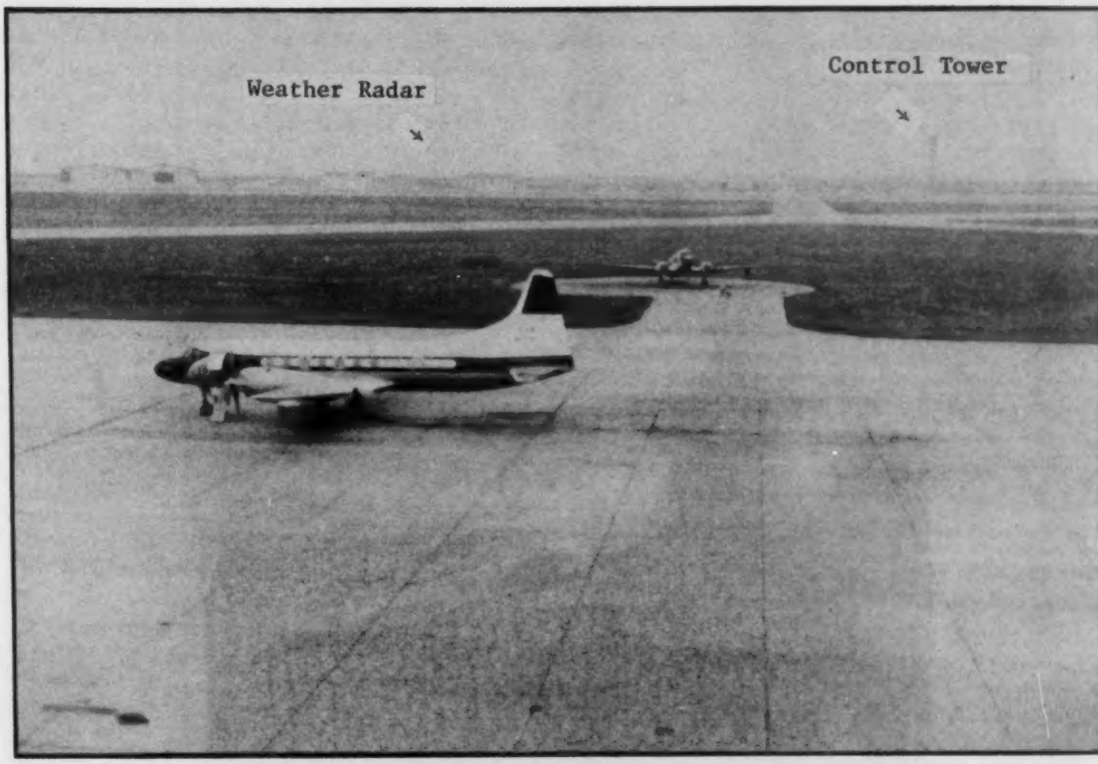


Figure 7. Convair 600

Table 6. Characteristics of a Narda Microwave Corporation Model 8300 broad band isotropic radiation monitor

Frequency range	0.3 to 18 GHz
Power reading ranges	Full scale (two ranges) 2 mW/cm² and 20 mW/cm²
Accuracy of isotropic probe calibration	±0.5 dB
Isotropic probe time constant	20 ms
Frequency sensitivity from 1 to 12 GHz from 0.85 to 16 GHz from 0.30 to 18 GHz	 ±0.5 dB +0.5, −1 dB +0.5, −3 dB
Isotropic response	±0.5 dB maximum deviation from energy incident in any direction except from and through handle
Response time, including time for meter indicator to to reach 90% of final steady state reading when subjected to a stepped input signal	1.2 s
Accuracy of instrumentation	±3% of full scale
Probe overload rating Continuous wave (cw) Peak (pulsed emissions)	 100 mW/cm² 20 W/cm²

Figure 8. Roof radome survey

Procedures

At the simulation lab, each of the two radars was individually set up so that the radar dish could be elevated to the roof-mounted radome where field measurements were obtained by standing on the flat portion of the roof in the vicinity of the radome. In this manner, a relatively free field situation prevailed, tending to minimize reflection problems. All data were collected with the radar dishes stopped in azimuthal rotation; this was necessary (a) to ensure that all readings were being taken in the

main radiation lobe of the transmitting dish, and (b) to obtain true readings of maximum levels because the time response of the indicator circuitry was slow. Once the dish was aligned as desired, the RF power was applied, and field measurements were made approaching the radome from a distance of approximately 100 feet. Once a rough feel for the magnitude of the fields was obtained, careful measurements were then made at successively shorter distances to the radome. All such measurements were obtained by holding the isotropic probe in one hand, the metering device in the other hand, and searching for the mainbeam of the dish at each distance. Distances were measured with a 100-foot steel tape laid on the roof. As one individual made the measurements, another recorded the data (field level and distance) at a lateral distance sufficient to not cause noticeable field reflections toward the survey probe. Data was taken in this manner until a distance was reached where the peak power density was equal to the burn-out limit for the survey instrumentation (20 W/cm^2). This peak field value was predetermined in terms of the meter indication of time average power density by taking into account the duty factor of each radar. In practical terms, this imposed a limit in the neighborhood of 15–18 mW/cm^2 average power density for the radars tested.

Figure 8 shows a typical survey reading being taken near the radome. After conducting the mainbeam field measurements for each radar, a survey of the area immediately adjacent to the radome was made, completely encircling the radome except for the mainbeam area in front of the antenna. These measurements were made to determine the possible existence of side lobes and a back lobe for the antenna. Figure 9 shows a measurement being made inside the radome but to the rear of the transmitting dish. In all cases, inadvertent exposure to individuals, other than the authors, was prevented by keeping other personnel off the roof.

A similar approach was used with those radars actually in an airplane. The planes were parked in open areas, clear of obstructions, adjacent to taxiways in accordance with FAA advice (*6*). Measurements were never taken with an airplane parked inside of a hangar. Under such conditions, reflections from other nearby aircraft could cause radar receiver crystal damage. Accordingly, when weather

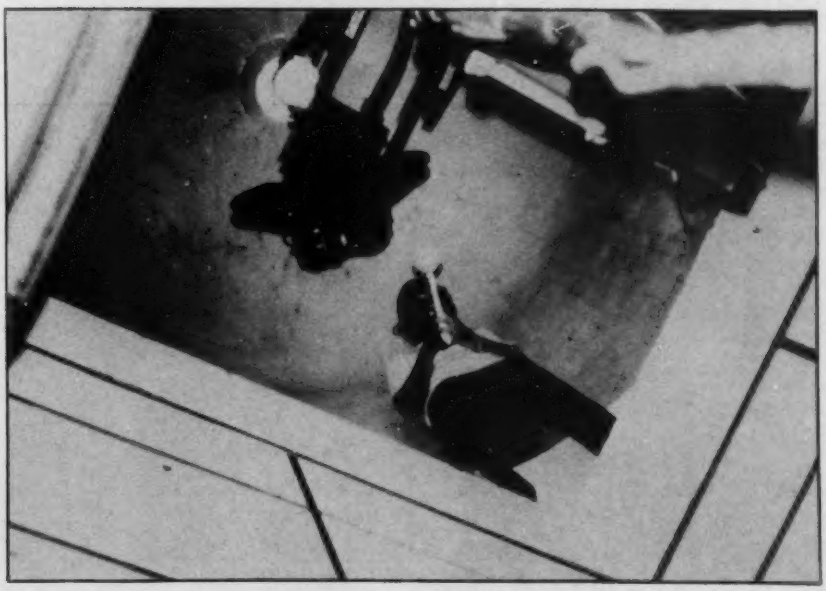


Figure 9. Measurement inside radome

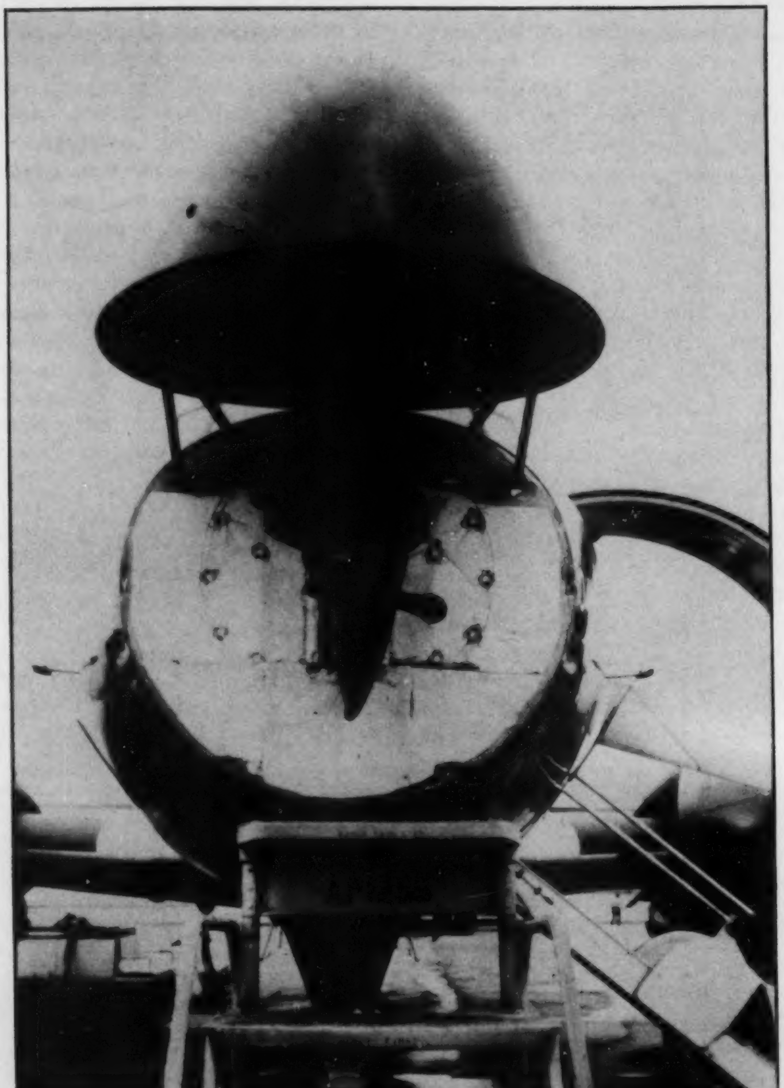


Figure 10. Convair with nose cone lifted

permitted, the selected airplane was moved to the outside location and the antenna fixed in position, pointing straight ahead of the plane. With the Convair 600 (figure 10) the nose cone was lifted on its hinge and measurements made as a function of distance, approaching the nose from a distance. Figure 11 is another picture of the survey of the Convair. Because of the height of the Convair nose above ground, the dish had to be pointed downward at approximately a 13° tilt in order that field measurements could be made from the ground. With

Figure 11. Survey of Convair

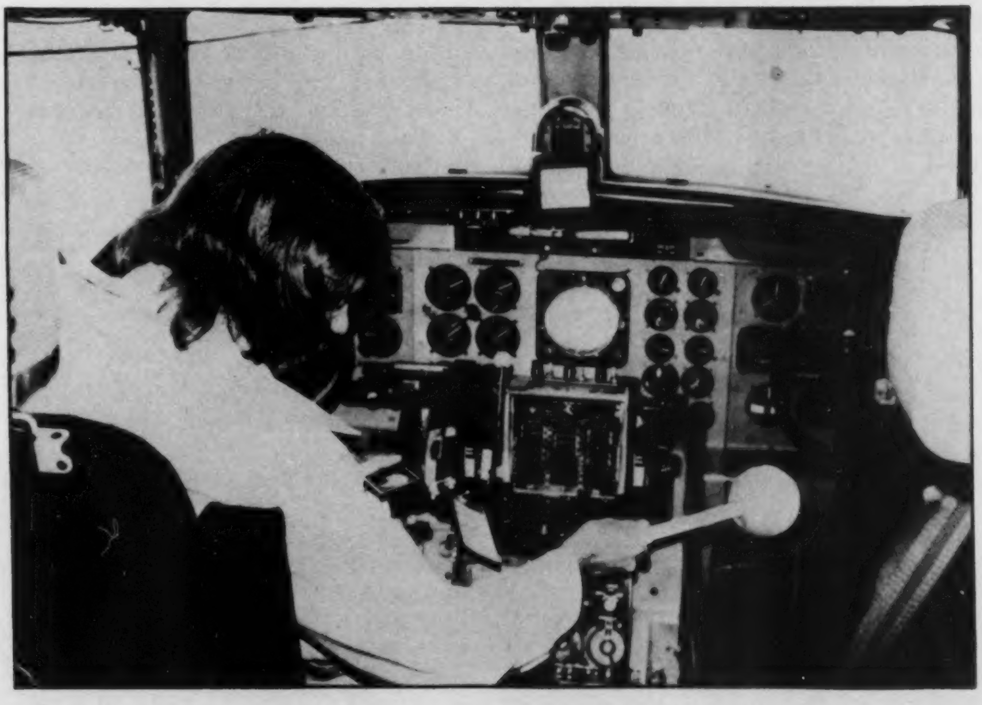


Figure 12. Survey of Convair cockpit

such an orientation, ground reflections were observed from the concrete apron at certain distances.

Once measurements on the dish axis were completed on the Convair, the antenna was repositioned until it pointed directly toward the cockpit, so that a survey of the cockpit could be made for possible radiation exposure (figure 12). The antenna was then positioned at various angles to enhance possible reflection from wings and other aircraft structures while additional cockpit measurements were made. Notice that the front of the fuselage is a flat metal plate which effectively shields the cockpit from the dish. This plate is covered with an absorptive, anechoic material to prevent receiver failure during the time that the antenna is rotating to the rear, since full 360 degree rotation is used by the AVQ-10.

Finally, a measurement was made of the attenuation properties of the nose cone itself, since our measurements were unattenuated ones. This was accomplished by lowering the nose cone, determining the radiation intensity at a known distance, and comparing with previous unattenuated values at the same distance.

Measurements on the WP-103 in the Sabre Liner were simplified in that the plane is smaller and consequently lower to the ground. This factor allowed the antenna to be kept nearly perfectly horizontal, and thus fewer ground reflection problems were observed. Also, due to the inconvenience of the operation, the nose cone itself was not removed. Instead, a portion of the fuselage shell near the nose cone was removed, so that adjustments could be made for stopping the normal antenna rotation. Figure 13 shows surveying around the Sabre Liner.

Results

The field intensity data resulting from our measurements are plotted in figures 14, 15, and 16. Survey data for the simulation lab measurements on a Bendix RDR-1B and the RCA AVQ-10 are shown in figure 14. Actual data points are graphed and a smooth curve was visually fitted through these points. Also shown on each graph is the distance at which the far field begins, as calculated by reference (*2*) and indicated under calculated data in tables 3, 4, and 5.

At various distances, more than one power density value was obtained. Such occurrences could be due to (a) practical difficulties encountered in relocating the same exact measurement position with respect to the main beam, and (b) apparent power fluctuations in the RF output from the radar transmitter. This was

Figure 13. Survey around Sabre Liner

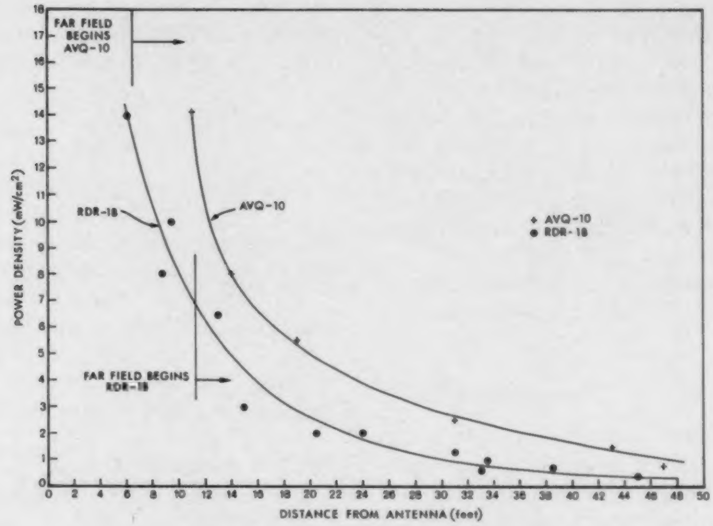


Figure 14. Measurements at simulation lab with radome

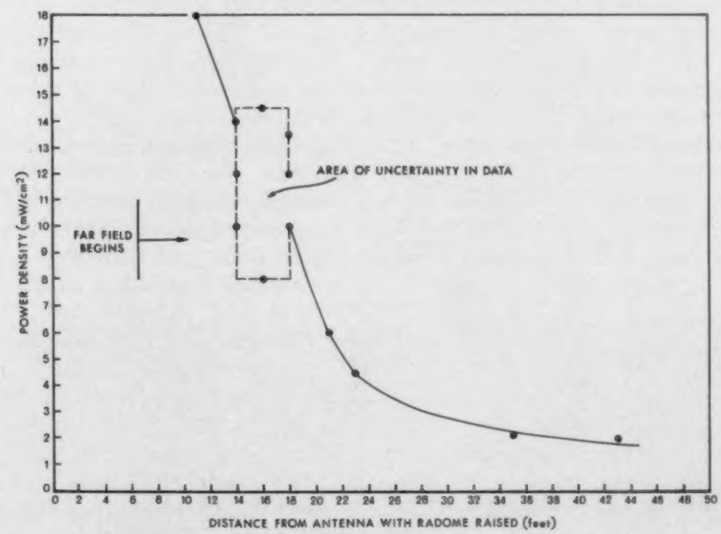


Figure 15. Measurements of RCA AVQ–10 in Convair 600

most evident in measurements on the RDR-1B and the Convair installation of the AVQ-10. In particular, stationary monitoring at a given distance would, from time to time, produce a variation in the power density reading, indicating some transmitter instability. However, notice that the area of data scatter in the RDR-1B measurements falls within the near field range and consequently is possibly an indication of the very erratic nature of this particular region of the exposure field, causing extreme difficulty in repositioning the probe to the same exact point, on a repetitive basis. Table 7 summarizes the data, indicating the distance at which the exposure power density was found to be 10 mW/cm² and 1 mW/cm²

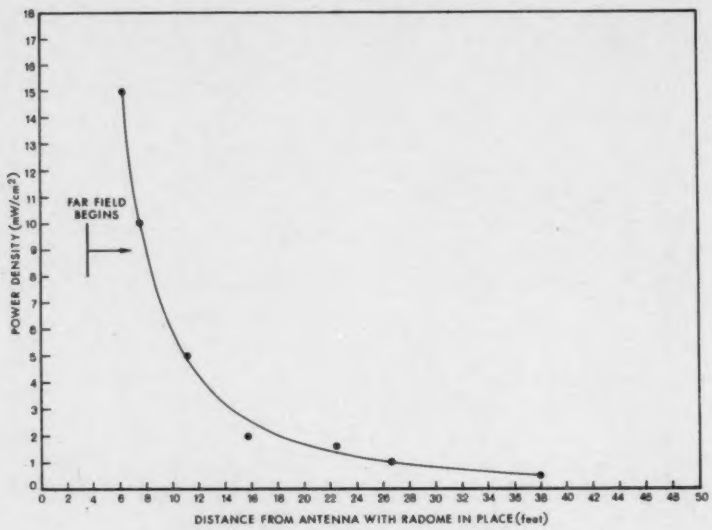


Figure 16. Measurements of Collins WP–103 in Sabre Liner

Table 7. Summary of exposures from radars

Radar configuration	Approximate distance (feet) to exposure of:	
	10 mW/cm²	1 mW/cm²
RDR–1B (simulation lab)	9	34
AVQ–10 (simulation lab)	12	47
AVQ–10 (Convair)	18	50+
WP–103 (Sabre Liner)	8	27

for each of the respective radar configurations. From the data, it appears that exposures in the neighborhood of 10 mW/cm² may occur in the general range of 8 to 18 feet from the antenna, dependent on the particular radar and conditions under which it might be measured (ground reflections included, radome losses, etc.).

Measurement of the Convair 600 nose cone radome showed an attenuation of approximately 5.5 dB or a power reduction factor of 0.28.

When measurements were made about the perimeter of the simulation lab radome, no detectable radiation lobes were apparent at the 0.2 mW/cm² level for either the RDR-1B or the AVQ-10. When approaching the transmitting dish at extremely close-in distances inside the radome, some low-level fields were observed at about 2 feet from the side of the dish.

A survey of the cockpit area of both the Sabre Liner and Convair 600 also showed that no detectable radiation at the 0.2 mW/cm² level was present (0.2 mW/cm² is the minimum detection capability of the Narda instrument). This was not surprising in the case of the Convair since a good shielding effect was produced by the fuselage shell between the cockpit and the radar antenna. With the Convair, the worst possible antenna position was used for these measurements—it was positioned directly toward the cockpit. Other directions were tried to see if reflections might occur from the wing or propeller structures on the aircraft causing scattering into the cockpit. Again, nothing detectable was observed in the cockpit (including ground reflection, radome losses, etc). However, when the probe was held at arm's length out of the pilot's window (left-hand side) some minimal upscale reading was observed (something slightly greater than 0.2 mW/cm²).

In similar measurements on the Sabre Liner, no detectable levels were found in the cockpit.

In this case, however, the radar dish is sector scanned and limited to principally the front 270° of view.

Conclusions

On the basis of this study, the following conclusions have been reached:

a. Typical maximum power for aircraft radars lies in the range 20 to 100 kW peak and 20 to 120 W average power.

b. Antenna gains are normally in the range of 25 to 30 dB.

c. Peak ERP is in the range of 6 MW to 100 MW while average ERP is in the range of 6 kW to 120 kW.

d. Exposures to power densities of 10 mW/cm² can occur in the range of 8 to 18 feet from the antenna.

e. Aircraft radomes can exhibit attenuations of about 5.5 dB.

f. No radiation levels in excess of 0.2 mW/cm² existed in the aircraft cockpits.

g. Normally, airborne radar antennas are rotating devices with either sector scanned or full 360 degree rotation at approximately 15 r/min.

h. In general, the radar beams on commercial aircraft are above 6 feet in height from the ground.

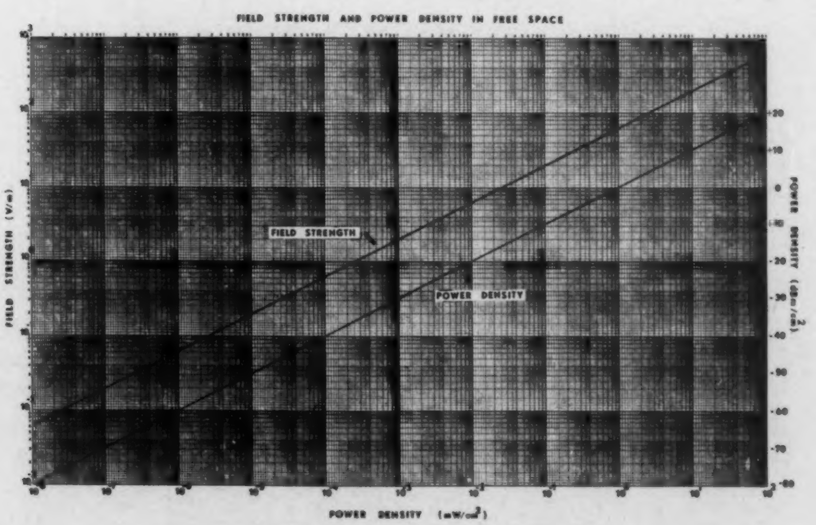
i. Reliable survey data can be obtained only by stopping the antenna rotation.

j. Reflections from nearby objects, including the ground, tend to cause irregularities in the field structure. Because of the unknown phase characteristics of the reflected waves, actual measurements are preferable to determine exposure in these situations.

k. Use of far field antenna gain was not reliable for predicting distances to the 10 mW/cm² exposure level.

Recommendations

Further investigation with respect to this study which could add useful information to the question of human exposure from airborne radar would be a determination of possible passenger exposure distances which can be found at airports. This information would prove interesting from the standpoint of an inadvertent exposure occurring when the airplane is parked near areas with passenger waiting rooms. Under such circumstances and depending upon the exact plane-waiting room configuration, potential short-burst radiation levels could be reasonably high. Assuming an instantaneous time average exposure of 5 mW/cm², the peak power density could be about 5 W/cm².



APPENDIX A. Field strength and power density in free space

VOLTAGE RATIO	POWER RATIO	dB	VOLTAGE RATIO	POWER RATIO	VOLTAGE RATIO	POWER RATIO	dB	VOLTAGE RATIO	POWER RATIO
1.0000	1.0000	0.00	1.0000	1.0000	.5129	.2630	5.8	1.950	3.802
.9988	.9977	0.01	1.0012	1.0023	.5070	.2570	5.9	1.972	3.890
.9977	.9954	0.02	1.0023	1.0046	.5012	.2512	6.0	1.995	3.931
.9966	.9931	0.03	1.0035	1.0069	.4955	.2455	6.1	2.018	4.074
.9954	.9908	0.04	1.0046	1.0093	.4898	.2399	6.2	2.042	4.169
.9943	.9886	0.05	1.0058	1.0116	.4842	.2344	6.3	2.065	4.266
.9931	.9863	0.06	1.0069	1.0139	.4786	.2291	6.4	2.089	4.365
.9920	.9840	0.07	1.0081	1.0162	.4732	.2239	6.5	2.113	4.467
.9908	.9817	0.08	1.0093	1.0186	.4677	.2188	6.6	2.138	4.571
.9897	.9795	0.09	1.0104	1.0209	.4624	.2138	6.7	2.163	4.677
.9886	.9772	0.1	1.012	1.023	.4571	.2089	6.8	2.188	4.786
.9772	.9550	0.2	1.023	1.047	.4519	.2042	6.9	2.213	4.898
.9661	.9333	0.3	1.035	1.072	.4467	.1995	7.0	2.239	5.012
.9550	.9120	0.4	1.047	1.096	.4416	.1950	7.1	2.265	5.129
.9441	.8913	0.5	1.059	1.122	.4365	.1905	7.2	2.291	5.248
.9333	.8710	0.6	1.072	1.148	.4315	.1862	7.3	2.317	5.370
.9226	.8511	0.7	1.084	1.175	.4266	.1820	7.4	2.344	5.495
.9120	.8318	0.8	1.096	1.202	.4217	.1778	7.5	2.371	5.623
.9016	.8128	0.9	1.109	1.230	.4169	.1738	7.6	2.399	5.754
.8913	.7943	1.0	1.122	1.259	.4121	.1698	7.7	2.427	5.888
.8810	.7762	1.1	1.135	1.288	.4074	.1660	7.8	2.455	6.026
.8710	.7586	1.2	1.148	1.318	.4027	.1622	7.9	2.483	6.166
.8610	.7413	1.3	1.161	1.349	.3981	.1585	8.0	2.512	6.310
.8511	.7244	1.4	1.175	1.380	.3936	.1549	8.1	2.541	6.457
.8414	.7079	1.5	1.189	1.413	.3890	.1514	8.2	2.570	6.607
.8318	.6918	1.6	1.202	1.445	.3846	.1479	8.3	2.600	6.761
.8222	.6761	1.7	1.216	1.479	.3802	.1445	8.4	2.630	6.918
.8128	.6607	1.8	1.230	1.514	.3758	.1413	8.5	2.661	7.079
.8035	.6457	1.9	1.245	1.549	.3715	.1380	8.6	2.692	7.244
.7943	.6310	2.0	1.259	1.585	.3673	.1349	8.7	2.723	7.413
.7852	.6166	2.1	1.274	1.622	.3631	.1318	8.8	2.754	7.586
.7762	.6026	2.2	1.288	1.660	.3589	.1288	8.9	2.786	7.762
.7674	.5888	2.3	1.303	1.698	.3548	.1259	9.0	2.818	7.943
.7586	.5754	2.4	1.318	1.738	.3508	.1230	9.1	2.851	8.128
.7499	.5623	2.5	1.334	1.778	.3467	.1202	9.2	2.884	8.318
.7413	.5495	2.6	1.349	1.820	.3428	.1175	9.3	2.917	8.511
.7328	.5370	2.7	1.365	1.862	.3388	.1148	9.4	2.951	8.710
.7244	.5248	2.8	1.380	1.905	.3350	.1122	9.5	2.985	8.913
.7161	.5129	2.9	1.396	1.950	.3311	.1096	9.6	3.020	9.120
.7079	.5012	3.0	1.413	1.995	.3273	.1072	9.7	3.055	9.333
.6998.	.4898	3.1	1.429	2.042	.3236	.1047	9.8	3.090	9.550
.6918	.4786	3.2	1.445	2.089	.3199	.1023	9.9	3.126	9.772
.6839	.4677	3.3	1.462	2.138	.3162	.1000	10.0	3.162	10.000
.6761	.4571	3.4	1.479	2.188	.2985	.08913	10.5	3.350	11.22
.6683	.4467	3.5	1.496	2.239	.2818	.07943	11.0	3.548	12.59
.6607	.4365	3.6	1.514	2.291	.2661	.07079	11.5	3.758	14.13
.6531	.4266	3.7	1.531	2.344	.2512	.06310	12.0	3.981	15.85
.6457	.4169	3.8	1.549	2.399	.2371	.05623	12.5	4.217	17.78
.6383	.4074	3.9	1.567	2.455	.2239	.05012	13.0	4.467	19.95
.6310	.3981	4.0	1.585	2.512	.2113	.04467	13.5	4.732	22.39
.6237	.3890	4.1	1.603	2.570	.1995	.03981	14.0	5.012	25.12
.6166	.3802	4.2	1.622	2.630	.1884	.03548	14.5	5.309	28.18
.6095	.3715	4.3	1.641	2.692	.1778	.03162	15.0	5.623	31.62
.6026	.3631	4.4	1.660	2.754	.1585	.02512	16.0	6.310	39.81
.5957	.3548	4.5	1.679	2.818	.1413	.01995	17.0	7.079	50.12
.5888	.3467	4.6	1.698	2.884	.1259	.01585	18.0	7.943	63.10
.5821	.3388	4.7	1.718	2.951	.1122	.01259	19.0	8.913	79.43
.5754	.3311	4.8	1.738	3.020	.1000	.01000	20.0	10.000	100.00
.5689	.3236	4.9	1.758	3.090	.03162	.00100	30.0	31.620	1,000.00
.5623	.3162	5.0	1.778	3.162	.01	.00010	40.0	100.00	10,000.00
.5559	.3090	5.1	1.799	3.236	.003162	.00001	50.0	316.20	10^5
.5495	.3020	5.2	1.820	3.311	.001	10^{-6}	60.0	1,000.00	10^6
.5433	.2951	5.3	1.841	3.388	.0003162	10^{-7}	70.0	3,162.00	10^7
.5370	.2884	5.4	1.862	3.467	.0001	10^{-8}	80.0	10,000.00	10^8
.5309	.2818	5.5	1.884	3.548	.00003162	10^{-9}	90.0	31,620.00	10^9
.5248	.2754	5.6	1.905	3.631	10^{-5}	10^{-10}	100.0	10^5	10^{10}
.5188	.2692	5.7	1.928	3.715					

Figure 15. APPENDIX B. Voltage and power ratios to dB

Acknowledgements

The authors are especially grateful to the FAA staff who assisted in this field trip: Dr. Robert N. Thompson and Mr. Jim D. Langwell of the Industrial Hygiene Section in the Civil Aeromedical Institute for their excellent cooperation and coordination of facilities and personnel involved in this measurement study; Mr. Harold K. Harvell, Chief of the Aircraft and Avionics Maintenance Branch, Aircraft Services Base, for his help in making arrangements for access to aircraft and the radar simulation lab; Mr. Alvin E. Kounovsky and Mr. George F. Bonner in the Avionics Maintenance Section, for their instruction and assistance in the operation of laboratory radar equipment; Mr. Jim L. McCloskey and Mr. John E. Burleson in the Avionics Maintenance Section for their patience and assistance in setup and operation of radars mounted in the airplanes.

REFERENCES

(*1*) Reference Data for Radio Engineers. Howard W. Sams and Co., Indianapolis, Ind. (1972) pp. 29-32.

(*2*) PALMISANO, W. A. and D. H. SLINEY, Instrumentation and methods used in microwave hazard analysis. Presented at the American Industrial Hygiene Association Meeting, Chicago, Ill. (4 May 1967).

(*3*) MUMFORD, W. W. Some technical aspects of microwave radiation hazards. Proceedings of the IRE (February 1961) pp. 427-447.

(*4*) U.S. AIR FORCE. Electromagnetic radiation hazards, Technical Manual T.O. 31Z-10-4, August 1966 revised June 1971.

(*5*) RUGGERA, P. S. and R. L. ELDER. Electromagnetic radiation interference with cardiac pacemakers, BRH/DEP 71-5. U.S. Department of Health, Education, and Welfare, Rockville, Md. 20852 (1971).

(*6*) FEDERAL AVIATION ADMINISTRATION. Recommended radiation safety precautions for airborne weather radars, AC No. 20-68. Federal Aviation Administration Advisory Circular (March 11, 1970).

Data

SECTION I. MILK AND FOOD

Milk Surveillance, November 1973

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 $\pm$ 0.08 g/liter for calcium and 1.51 $\pm$ 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Research and Development conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category				Experimental 2σ error (pCi/liter)
		Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131:	(96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
	(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137:	(53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
	(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89:	(29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
	(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90:	(32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
	(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels ≥50 pCi/liter;
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels ≥20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4-10 pCi/liter for levels <100 pCi/liter; 4-10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports*.

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports*. The relationship between the

Table 2. Concentrations of radionuclides in milk for November 1973 and 12-month period December 1972 through November 1973

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:						
Ala:	Montgomery[c]	P	NA	5	0	4
Alaska:	Palmer[c]	P	NA	4	0	1
Ariz:	Phoenix[c]	P	NA	0	0	0
Ark:	Little Rock[c]	P	NS	9	NS	1
Calif:	Los Angeles[c]	P	NA	0	0	0
	Sacramento[c]	P	NA	1	0	0
	San Francisco[c]	P	NA	0	0	0
	Del Norte	P	11	10	0	6
	Fresno	P	0	1	0	2
	Humboldt	P	2	3	0	1
	Los Angeles	P	0	1	0	1
	Mendocino	P	2	2	0	3
	Sacramento	P	0	2	0	2
	San Diego	P	0	1	0	2
	Santa Clara	P	0	2	0	2
	Shasta	P	2	2	0	2
	Sonoma	P	0	2	0	2
Colo:	Denver[c]	P	NS	3	NS	0
	East	R	NS		NS	22
	Northeast	R	NS		NS	0
	Northwest	R	NA		[d]0 (3)	2
	South Central	R	NS		NS	NS
	Southeast	R	NS		NS	0
	Southwest	R	NA		[d]0	0
	West	R	NA		[d]0	0
Conn:	Hartford[c]	P	NA	4	0	4
	Central	P	NA		0	0
Del:	Wilmington[c]	P	NA	5	0	2
D.C:	Washington[c]	P	NA	3	0	1
Fla:	Tampa[c]	P	NA	4	22	27
	Central	R	5	6	21	28
	North	R	4	6	24	14
	Northeast	R	6	6	11	31
	Southeast	R	6	5	32	49
	Tampa Bay area	P	5	5	31	29
	West	R	8	8	28	9
Ga:	Atlanta[c]	P	NA	4	0	5
Hawaii:	Honolulu[c]	P	NA	0	0	0
Idaho:	Idaho Falls[c]	P	NA	3	0	0
Ill:	Chicago[c]	P	NA	5	0	1
Ind:	Indianapolis[c]	P	NA	4	0	2
	Central	P	5	6	10	7
	Northeast	P	6	5	10	9
	Northwest	P	7	7	0	8
	Southeast	P	6	6	0	7
	Southwest	P	6	7	0	8
Iowa:	Des Moines[c]	P	NA	4	0	0
	Des Moines	P	4	5	0 (3)	0
	Iowa City	P	NS	5	NS	0
	LeMars	P	4	4	NS	2
	Little Cedar	P	6	6	0	0
Kans:	Wichita[c]	P	NA	5	11	1
	Coffeyville	P	6	7	0	7
	Dodge City	P	3	5	0	6
	Falls City, Nebr	P	5	6	0	5
	Hays	P	5	7	0	5
	Kansas City	P	NS	5	NS	7
	Topeka	P	8	8	0	5
	Wichita	P	7	7	3	6
Ky:	Louisville[c]	P	NA	5	0	2
La:	New Orleans[c]	P	NS	8	NS	1
Maine:	Portland[c]	P	NA	5	12	16
Md:	Baltimore[c]	P	NA	6	0	3
Mass:	Boston[c]	P	NA	7	0	12
Mich:	Detroit[c]	P	NA	6	15	3
	Grand Rapids[c]	P	NA	7	0	1
	Bay City	P	NA	8	12	1
	Charlevoix	P	NA	8	0	2
	Detroit	P	NA	6	0	0
	Grand Rapids	P	NA	8	0	2
	Lansing	P	NA	9	0	3
	Marquette	P	NA	9	0 (2)	8
	Monroe	P	NA	11	0 (2)	1
	South Haven	P	NA	11	0 (3)	3
Minn:	Minneapolis[c]	P	NA	7	0	2
	Bemidji	P	NA	7	0	11
	Duluth	P	NA	16	0	18
	Fergus Falls	P	NA	7	0	0
	Little Falls	P	NA	18	0	26
	Mankato	P	NA	5	0	0
	Marshall	P	NA	4	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for November 1973 and 12-month period, December 1972 through November 1973—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
Minn:	Minneapolis	P	NA	16	0	0
	Rochester	P	NA	6	0	0
Miss:	Jackson[c]	P	NA	8	0	6
Mo:	Kansas City[c]	P	NA	4	0	0
	St. Louis[c]	P	NA	7	0	1
Mont:	Helena[c]	P	NA	2	0	0
Nebr:	Omaha[c]	P	NA	3	0	0
Nev:	Las Vegas[c]	P	NS	4	NS	0
N.H:	Manchester[c]	P	NA	8	14	9
N.J:	Trenton[c]	P	NA	5	0	3
N. Mex:	Albuquerque[c]	P	NA	0	0	0
N.Y:	Buffalo[c]	P	NA	4	0	3
	New York City[c]	P	NA	5	0	3
	Syracuse[c]	P	NA	6	0	1
	Albany	P	5	4	0	0
	Buffalo	P	NA	4	26	0
	Massena	P	NA	6	16	0
	New York City	P	NA	7	0	0
	Syracuse	P	NA	5	0	0
N.C:	Charlotte[c]	P	NA	7	0	5
N. Dak:	Minot[c]	P	NA	7	0	0
Ohio:	Cincinnati[c]	P	NA	5	20	3
	Cleveland[c]	P	NA	6	0	2
Okla:	Oklahoma City[c]	P	NA	3	0	0
Oreg:	Portland[c]	P	NA	3	0	1
	Baker	P	NA		[d]0	1
	Coos Bay	P	NA		[d]0	4
	Eugene	P	NA		[d]0	0
	Medford	P	NA		[d]0	1
	Portland composite	P	NA		[d]0	0
	Portland local	P	NA		[d]0	2
	Redmond	P	NA		[d]0	1
	Tillamook	P	NA		[d]0	8
Pa:	Philadelphia	P	NA	5	0	2
	Pittsburgh[c]	P	NA	8	0	4
	Dauphin	P	4	4	0	0
	Erie	P	8	6	0	0
	Philadelphia	P	3	3	0	1
	Pittsburgh	P	4	5	0	0
R.I:	Providence[c]	P	NA	5	0	6
S.C:	Charleston[c]	P	NA	6	0	5
	Chapin	R	NS	8	NS	11
	Clemson	R	NS	8	NS	7
	Columbia	R	8	8	6	9
	Fairfield	R	NS	7	NS	13
	Hartsville-02	R	6	7	9	12
	Hartsville-03	R	NS	16	NS	15
	Lee County	R	8	7	8	16
	Oconee County	R	NS	8	NS	8
	Pickens	R	NS	7	NS	6
	Williston	R	NS	7	NS	15
	Winnsboro	R	NS	7	NS	16
S. Dak:	Rapid City[c]	P	NA	5	0	1
Tenn:	Chattanooga[c]	P	NA	6	0	2
	Knoxville[c]	P	NA	0	0	0
	Memphis[c]	P	NA	6	0	2
	Chattanooga	P	7	8	0	3
	Clinton	R	8	4	11	4
	Fayetteville	R	8	7	0	3
	Kingston	R	9	6	0	0
	Knoxville	P	5	3	0	2
	Lawrenceburg	R	NS	6	NS	6
	Nashville	P	NS	3	NS	0
	Pulaski	R	0	6	0	0
	Sequoyah	R	NS	9	NS	0
Tex:	Austin[c]	P	NA	0	0	0
	Dallas[c]	P	NA	3	0	0
Utah:	Salt Lake City[c]	P	NA	2	0	1
Vt:	Burlington[c]	P	NA	4	16	6
Va:	Norfolk[c]	P	NA	6	0	2
Wash:	Seattle[c]	P	NA	2	0	0
	Spokane[c]	P	NA	5	0	0
	Benton County	R	0	1	0	0
	Franklin County	R	NS	1	NS	0
	Longview	R	6	4	0	3
	Sandpoint, Idaho	R	3	6	12	1
	Skagit County	R	7	4	0	0
W. Va:	Charleston[c]	P	NA	6	0	2
Wisc:	Milwaukee[c]	P	NA	4	0	1
Wyo:	Laramie[c]	P	NA	1	0	1

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for November 1973 and 12-month period December 1972 through November 1973—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA:						
Alberta:	Calgary	P	NA		0	9
	Edmonton	P	NA		0	13
British Columbia:	Vancouver	P	NA		0	13
Manitoba:	Winnipeg	P	NA		10	10
New Brunswick:	Moncton	P	NA		0	9
Newfoundland:	St. John's	P	NA		13	16
Nova Scotia:	Halifax	P	NA		0	11
Ontario:	Ottawa	P	NA		0	6
	Sault Ste. Marie	P	NA		14	16
	Thunder Bay	P	NA		0	12
	Toronto	P	NA		0	7
	Windsor	P	NA		0	6
Quebec:	Montreal	P	NA		0	7
	Quebec	P	NA		10	13
Saskatchewan:	Regina	P	NA		0	8
	Saskatoon	P	NA		0	8
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal[c]	P	NS	0	NS	11
Chile:	Santiago	P	0	0	0	0
Colombia:	Bogota	P	NS	1	NS	0
Ecuador:	Guayaquil	P	0	1	0	0
Jamaica:	Mandeville	P	NS	2	NS	23
Puerto Rico:	San Juan[c]	P	NA	2	0	2
Venezuella:	Caracas	P	0	1	0	2
PMN network average[e]			0	4	2	3

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] The practical reporting level for this network differs from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:
Cesium-137: Colorado—25 pCi/liter; Oregon—15 pCi/liter.

[e] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for

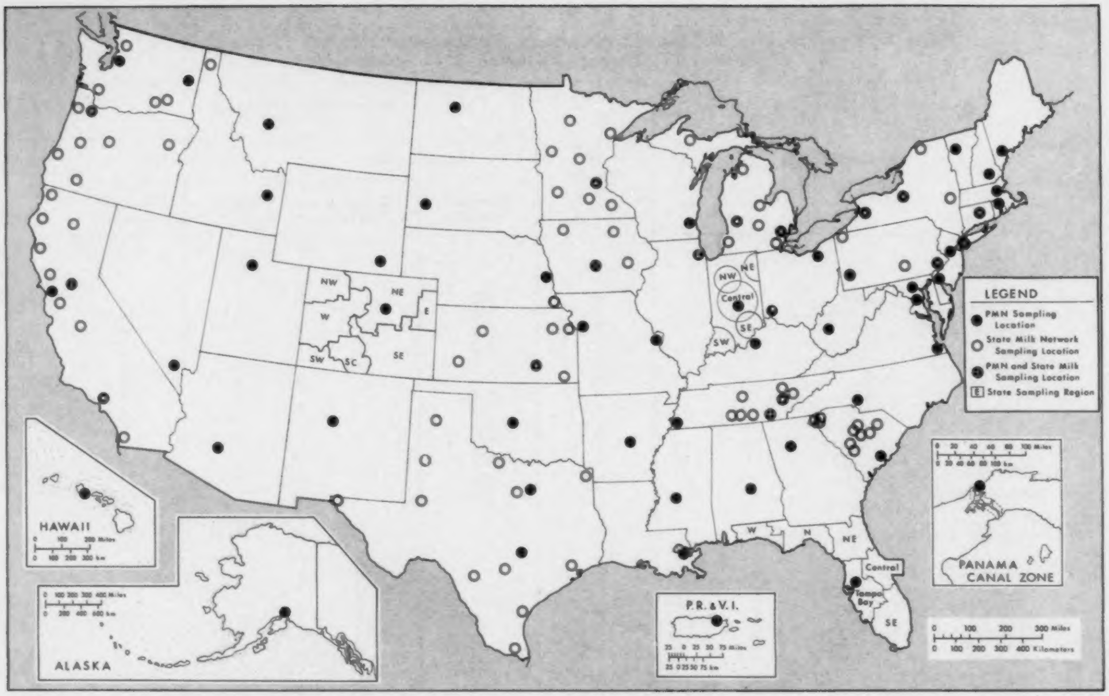


Figure 2. State and PMN milk sampling stations in the United States

strontium-90 and cesium-137 for November 1973 and the 12-month period, December 1972 to November 1973. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for November 1973 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 11 pCi/liter in the United States for November 1973 and the highest 12-month average was 18 pCi/liter (Little Falls, Minn.) representing 9.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 32 pCi/liter in the United States for November 1973, and the highest 12-month average was 49 pCi/liter (Southeast Florida) representing 1.4 percent of the value derived from the recommendations given in the Federal Radiation Council report.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Radiation Control Unit
Health Services Division
Washington Department of Social and Health Services

REFERENCES

(*1*) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER, and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Pub Health 49:225 (February 1969).

(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory study of iodine–131, cesium–137, strontium–89, and strontium–90 measurements in milk, June 1972, Technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet	July 1971–December 1972	February 1974
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Institutional Diet	April–June 1973	March 1974
Strontium-90 in Tri-City Diets	1972	December 1973

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
Florida	1969	January 1972
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Minnesota	July 1971–June 1972	March 1974
New York	July–December 1971	August 1973
North Carolina	1968–1970	September 1972
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Tritium Surveillance System	April–June 1973	October 1973
Washington	July 1970–June 1971	August 1973

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Florida Waters, 1970[1]

Radiological and Occupational Health Section
Florida State Division of Health

The Florida State Division of Health samples raw surface, ground, and treated water in 13 hydrological subbasins as shown in figure 1. Samples collected on a variable frequency and analyzed for gross alpha and beta radioactivity during 1970 are presented in table 1.

In addition to sampling being done by the Florida State Division of Health, the Bioenvironmental Engineering Research Laboratory, University of Florida, samples surface, ground, and municipal water in Alachua County for gross beta radioactivity. Samples are taken monthly from each sampling point with the exception of the City of Gainesville where raw water is sampled daily. These data for 1970 are summarized in table 2. Gross beta radioactivity above the minimum reported concentration was detected in 6 water samples taken in Alachua

[1] Data taken from "Report of Florida Radiological Surveillance Programs, 1970," Bureau of Preventable Diseases, Radiological and Occupational Health Section, Jacksonville, Fla.

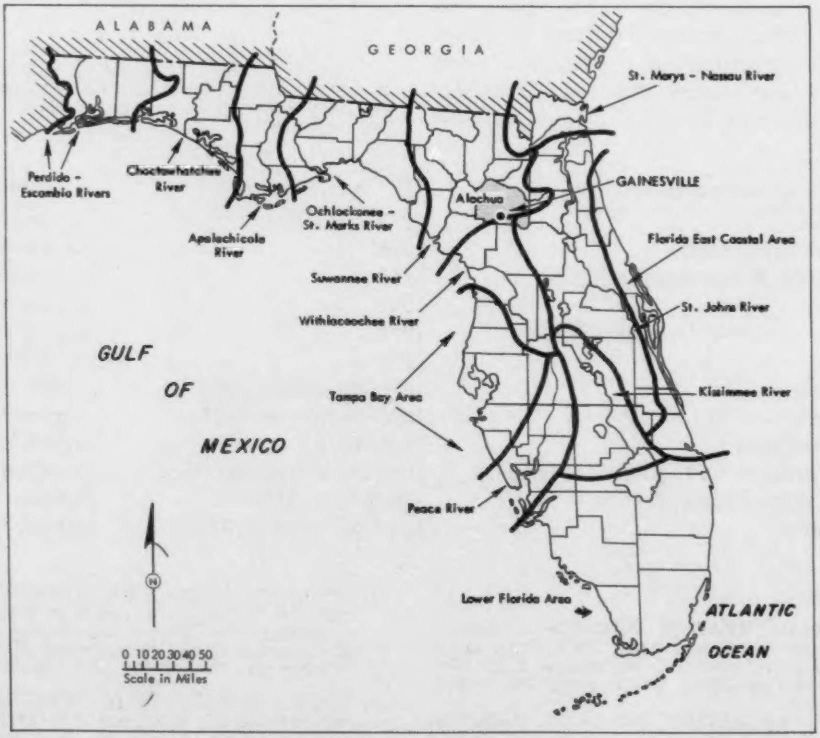


Figure 1. Hydrological surface subbasins in Florida

Table 1. Gross alpha and beta radioactivity in Florida water, 1970

Location	Number of samples	Alpha (pCi/liter)	Beta (pCi/liter)
St. John's River:			
Raw	15	<7	<10
	1	<7	20
Treated	6	<7	<10
Sewage treatment plants	• 3	<7	<10
	1	<7	16
	1	<7	20
St. Mary's, Nassau, and Amelia Rivers:			
Raw	1	<7	17
	2	<7	<10
Lower Florida area:			
Raw	1	<7	14
	1	<7	10
	1	<7	<10
Treated	7	<7	<10
Sewage treatment plant	• 2	<7	38
	• 2	<7	22
	• 1	<7	18
	• 1	<7	14
	• 1	<7	12
	• 1	<7	11
	• 5	<7	<10
Florida East Coastal area:			
Raw	1	<7	<10
Treated	3	<7	<10
Kissimmee River Basin:			
Treated	1	<7	12
Sewage treatment plant	• 2	<7	<10
Peace River:			
Treated	1	<7	<10
Tampa Bay area:			
Raw	1	<7	<10
Sewage treatment plants	• 1	<7	18
	• 1	<7	11
	• 2	<7	<10
Withlacoochee and Waccasassa Rivers:			
Treated	2	<7	<10

• Composite sample

County. The 6 samples averaged 13 pCi/liter of gross beta radioactivity.

During 1970, only 18 samples out of a total of 68 collected from 45 sampling sites showed gross beta radioactivity greater than the minimum reported concentration. The 18 surface, ground, and municipal water samples averaged 18 pCi/liter. The average gross beta radioactivity in water samples is well below the limitations imposed by the standard for gross beta radioactivity in drinking water (1 000 pCi/liter) (*1*).

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Public Health Service Drinking Water Standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Table 2. Gross beta radioactivity in Florida water, 1970

Location	Radioactivity concentration (pCi/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Summary
Alachua County: (18 sampling locations)													
Maximum	19.0	13.10	5.48	—	—	—	13.10	—	—	11.40	—	—	19.0
Average	3.25	5.65	1.90	NS	NS	NS	4.70	NS	NS	4.45	NS	NS	3.99
City of Gainesville:													
Maximum	8.84	10.5	10.1	7.59	2.95	7.58	5.9	3.79	NS	10.90	6.32	7.58	10.90
Average	2.53	4.24	2.62	2.82	1.5	3.79	2.02	1.85	—	5.04	2.86	4.07	3.03

NS, no sample collected.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Pan American Health Organization and the California Department of Health.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	1971	August 1973
Mexican air monitoring program	January–December 1973	December 1973
Plutonium in airborne particulates	October–December 1972	June 1973
Surface air sampling program, 80th Meridian Network, *HASL*	1971	September 1973

1. Radiation Alert Network November 1973

Eastern Environmental Radiation Facility, Montgomery
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which gathers samples at 68 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during November 1973.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, November 1973

Station location [a]	Number of samples	Gross beta radioactivity (pCi/m^3)						Precipitation	
		5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
		Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m^2)
Ala: Montgomery	9	1	0	1	0.03	<0.01	0.02	93	<0.1
Calif: Berkeley	9	0	0	0	.02	<.01	<.01	37	<.04
Los Angeles	9	1	0	1	.04	.01	.02		
Colo: Denver	9	2	0	1	.08	.02	.04	3	.03
Ind: Indianapolis	19	2	0	0	.04	.01	.02		
Nev: Las Vegas	9	2	0	1	.04	.02	.03		
N. Mex: Sante Fe	0								
N.Y: Buffalo	9	1	0	0	.03	.01	.02	3	.01
N. Dak: Bismarck	9	2	0	1	.04	.01	.03	10	.05
Ohio: Columbus	4	1	0	1	.06	.02	.03		
Okla: Oklahoma City	0								
Oreg: Portland	20	0	0	0	.02	<.01	.01		
Pa: Harrisburg	18	2	0	1	.05	<.01	.02		
S.C: Columbia	7	1	0	1	.04	.02	.03	5	.04
Network summary	131	2	0	1	0.08	<0.01	0.03	25	0.02

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network November 1973

National Environmental Research Center—Las Vegas[1]
Environmental Protection Agency

The Air Surveillance Network (ASN),[2] operated by the National Environmental Research Center—Las Vegas (NERC–LV), consists of 49 active and 72 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports*.

Results

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m^3. For reporting purposes, concentrations less than 1.0 pCi/m^3 are reported to 1 significant figure, and those equal to or greater than 1.0 pCi/m^3 are reported to 2 significant figures. For averaging purposes individual concentration values less than the minimum detectable concentration ($\sim$0.03 pCi/m^3 for a 700 m^3 sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are as follows:

[1] Formerly the Western Environmental Research Laboratory.
[2] The ASN is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

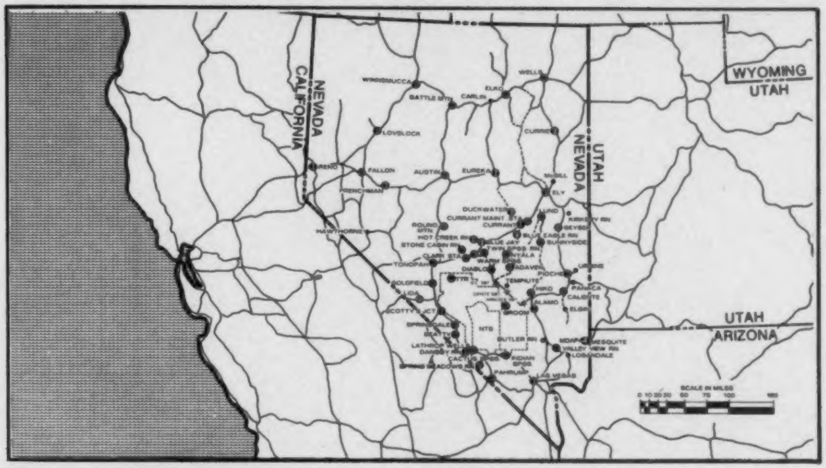


Figure 2. NERC–LV Air Surveillance Network stations in Nevada

Figure 3. NERC–LV Air Surveillance Network stations outside Nevada

Concentration (pCi/m³)	Reported value of concentration above MDC (pCi/m³)	Reported value of concentration below MDC (pCi/m³)
<0.05	<0.1	<0.1
≧0.05 <0.15	0.1	<0.1
≧0.15	As calculated and rounded	<calculated MDC

As shown in table 1, the highest gross beta concentration at continuously operated stations within the network was 0.3 pCi/m³ at Blue Jay, Nev. No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges during November 1973.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

Table 2. Summary of gross beta radioactivity concentrations in air, November 1973

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average
Ariz:	Kingman	20	0.1	<0.1	0.1
	Seligman	13	.1	<.1	.1
Calif:	Baker	13	.1	<.1	.1
	Barstow	14	.1	<.1	<.1
	Bishop	13	.1	<.1	.1
	Death Valley Junction	14	.1	<.1	.1
	Furnace Creek	13	.1	<.1	.1
	Lone Pine	9	.1	<.1	<.1
	Needles	12	.1	<.1	.1
	Ridgecrest	13	.1	<.1	<.1
	Shoshone	13	.1	<.1	<.1
Nev:	Alamo	13	.1	<.1	.1
	Austin	11	.1	<.1	<.1
	Beatty	13	.1	<.1	<.1
	Blue Eagle Ranch (Currant)	13	.1	<.1	<.1
	Blue Jay	13	.3	<.1	.1
	Caliente	13	.1	<.1	.1
	Currant Ranch	13	.1	<.1	<.1
	Diablo	13	.1	<.1	<.1
	Duckwater	10	.1	<.1	<.1
	Ely	13	<.1	<.1	<.1
	Eureka	13	.1	<.1	<.1
	Fallini's Twin Springs Ranch	13	.1	<.1	.1
	Geyser Ranch (Pioche)	12	.1	<.1	.1
	Goldfield	13	<.1	<.1	<.1
	Groom Lake	11	.1	<.1	.1
	Hiko	13	.1	<.1	.1
	Indian Springs	13	.1	<.1	<.1
	Las Vegas	18	.1	<.1	.1
	Lathrop Wells	8	.1	<.1	.1
	Lida	13	.1	<.1	<.1
	Lund	12	.1	<.1	<.1
	Mesquite	13	.1	<.1	.1
	Nyala	13	.1	<.1	<.1
	Pahrump	13	.1	<.1	<.1
	Pioche	13	.2	<.1	<.1
	Round Mountain	13	.1	<.1	<.1
	Scotty's Junction	13	.1	<.1	<.1
	Stone Cabin Ranch	13	.1	<.1	<.1
	Sunnyside	14	.2	<.1	<.1
	Tonopah	13	.1	<.1	<.1
	Tonopah Test Range	9	.1	<.1	.1
	Warm Springs	9	.1	<.1	<.1
	Warm Springs Ranch	13	.1	<.1	.1
Utah:	Cedar City	10	.2	<.1	<.1
	Delta	9	.2	<.1	.1
	Garrison	13	.2	<.1	.1
	Milford	11	.1	<.1	<.1
	St. George	13	.2	<.1	.1

3. Canadian Air and Precipitation Monitoring Program,[3] November 1973

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

[3] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for November 1973 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, November 1973

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.04	0.01	0.02	12	0.27
Coral Harbour	4	.04	.01	.03	23	.26
Edmonton	4	.04	.02	.03	9	.40
Ft. Churchill	4	.04	.01	.02	3	.21
Fredericton	2	.03	.03	.03	6	.57
Goose Bay	1	.01	.01	.01	4	.38
Halifax	4	.03	.02	.02	8	.53
Inuvik	3	.02	.02	.02	9	.12
Montreal	4	.01	<.01	.01	19	1.20
Moosonee	4	.03	.01	.02	1	.03
Ottawa	3	.02	.01	.01	15	.88
Quebec	3	.02	.01	.01	7	.52
Regina	4	.04	.02	.03	10	.23
Resolute	4	.04	.02	.03	7	.13
St. John's, Nfld	4	.02	.01	.02	NS	NS
Saskatoon	4	.04	.03	.03	6	.23
Sault Ste. Marie	4	.02	.01	.02	9	.70
Thunder Bay	4	.03	.01	.02	11	.95
Toronto	1	.03	.03	.03	18	1.70
Vancouver	4	.01	.01	.01	4	.66
Whitehorse	4	.05	.02	.03	9	.21
Windsor	NS				9	.86
Winnipeg	2	.01	<.01	.01	10	.39
Yellowknife	3	.03	.02	.02	12	.32
Network summary	78	0.05	<0.01	0.02	10	0.51

NS, no sample.

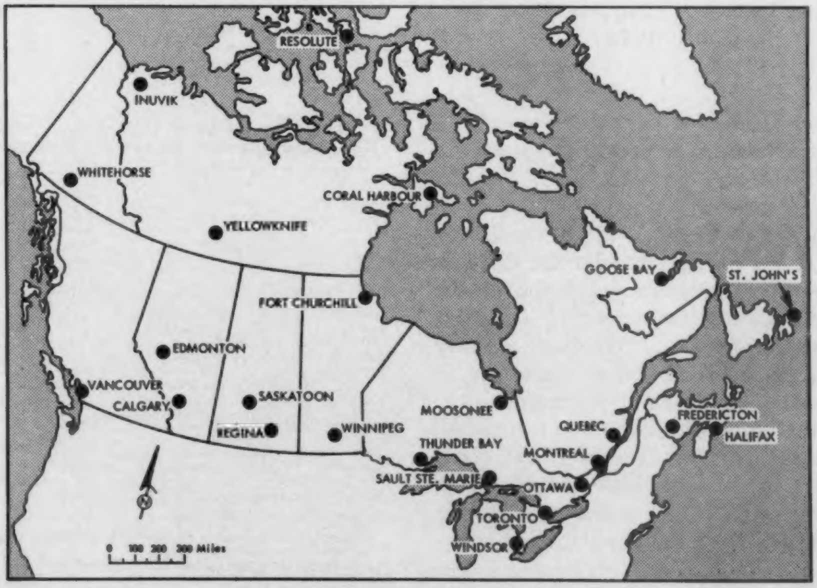


Figure 4. Canadian air and precipitation sampling stations

REFERENCES

(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

Figure 5. Pan American Air Sampling Program stations

4. Pan American Air Sampling Program November 1973

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports.* The November 1973 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, November 1973

Station location		Number of samples	Gross beta radioactivity (pCi/m^3)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	13	0.01	0.00	0.01
Chile:	Santiago	30	.01	.00	.01
Colombia:	Bogota	21	.00	.00	.00
Ecuador:	Cuenca	5	.02	.00	.01
	Guayaquil	18	.02	.01	.01
	Quito	15	.01	.00	.00
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	0			
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	16	.01	.00	.00
Pan American summary		118	0.02	0.00	0.01

[a] The monthly average is calculated by weighting the individual samples with length of sampling period.
Values less than 0.005 pCi/m^3 are reported and used in averaging 0.00 pCi/m^3.

5. California Air Sampling Program November 1973

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health where they are analyzed for their radioactive content.

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2-cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha and beta radioactivity, 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. Table 5 presents the monthly gross beta radioactivity in air for November. The monthly sample results are presented quarterly.

Figure 6. California air sampling program stations

Table 5. Gross beta radioactivity in California air, November 1973

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	25	1.05	0.01	0.33
Barstow	30	1.03	.03	.19
Berkeley	28	.37	.00	.05
El Centro	30	.75	.04	.14
Eureka	30	.11	.00	.03
Fresno	30	.68	.02	.18
Los Angeles	30	.18	.00	.07
Redding	30	.14	.01	.07
Sacramento	30	.24	.02	.07
Salinas	30	.66	.02	.18
San Bernardino	30	.60	.02	.14
San Diego	30	.34	.05	.10
San Luis Obispo	30	.34	.00	.08
Santa Rosa	30	.22	.00	.04
Summary	413	1.05	0.00	0.12

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for Hanford Atomic Products Operation.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Hanford Atomic Products Operation[2] January–December 1970

Battelle Pacific Northwest Laboratories Richland, Wash.

The primary mission at the Hanford site of the Atomic Energy Commission (AEC) has been the production of plutonium. Activities have included nuclear fuel fabrication, plutonium production and test reactor operation, chemical separations of irradiated fuels, laboratory support and research, waste storage and disposal, and plant support operations. In recent years, privately-owned facilities located within the Hanford site boundaries have included a power generating station, an office building, and a radioactive waste burial site.

Low-level wastes from Hanford operations, fallout from nuclear weapons testing, naturally-occurring radioelements, and cosmic radiation all contribute to radioactivity in the Hanford environs. The most significant Hanford contributions to off-plant radioactivity and consequent population doses have usually originated with reactor cooling water released to the Columbia River (*1–3*). Between December 1964 and December 1970, all but one (KE) of the eight production reactors with once-through cooling were deactivated. The only other production reactor remaining in operation at Hanford during 1970 was N reactor, which has a closed primary cooling loop and releases only minor quantities of radioactivity to the river.

The purpose of this annual report is to present an evaluation of the combined offsite effects of the radioactive effluents released to uncontrolled areas by all Hanford contractors during 1970.

The Hanford site is in a semiarid region of southeastern Washington State (figure 1) where the average rainfall is about 16 cm (6 inches). This section of the State has a

[2] Summarized from Pacific Northwest Laboratory, "Environmental Surveillance at Hanford for 1970," BNWL–1669 (September 1973).

Figure 1. Hanford project environs

sparse covering of natural vegetation primarily suited for grazing, although large areas near the site have gradually been put under irrigation during the past few years. The plant site covers an area of about 1300 km^2 (500 square miles). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Prevailing winds near the plant production sites are from the northwest, with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The nearest population center is the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity include Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant together with the surrounding agricultural area, is about 100 000.

The farming area closest to Hanford is on Wahluke Slope, about 11 km (7 miles) from N reactor but much of the land east and south of the project boundary is under cultivation. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two

small irrigated areas using Columbia River water taken downstream from the reactor are the Ringold farms and the Riverview district west of Pasco. These are about 40 km (25 miles) and 70 km (45 miles), respectively, downstream from the N reactor. The principal products from the larger farm plots are hay, fruit, beef, and dairy products.

Sources and levels of environmental radioactivity

Radioactive wastes continued to be generated during 1970 by the KE and N production reactors, the chemical processing plants, and the laboratories. High-level wastes were concentrated and retained in storage in the chemical processing areas. Controlled releases of low-level wastes, for which concentration and storage were not feasible, were made to the ground, to the atmosphere, and to the Columbia River.

Changes of significance in plant operations during 1970 included the retirement in February of KW reactor, the seventh of the eight Hanford production reactors using single-pass cooling to be retired since 1964. Two plutonium production reactors, one single-pass (KE) and one recirculating coolant dual-purpose reactor (N), remained in operation. From February to April and again in September, no reactors were operating.

A marked reduction from 1969 occurred in releases of radioiodine from the chemical processing facilities. Effects of a reported atmospheric nuclear weapons test were detected temporarily in air and milk in December.

In late December 1969, two ducks collected during routine surveillance from the K reactor area trench were found to contain greater amounts of radioactivity, primarily phosphorus–32, than birds taken from the river. The trench received single-pass reactor coolant, and the ducks had apparently consumed algae from this site. Initial followup in January 1970, involved collection of waterfowl from all open ponds and trenches at the Hanford site. One duck was found at the K trench and one more with unusually high phosphorus–32 concentrations was found residing on the N reactor trench. Corrective action was taken to prevent further access by gamebirds. As in past years, none of the many gamebirds collected along the river and close to public hunting areas showed any similar concentrations of radionuclides.

Radioactivity in the Columbia River

Nuclides present in reactor effluent

Cooling of the Hanford production reactors (with the exception of N reactor) is accomplished by a single pass of treated Columbia River water. The N reactor uses recirculating demineralized water as a primary coolant. Some cooling water containing radioactive material is discharged to a ground disposal site with overflow to the N trench; liquid wastes are collected and transported to the chemical processing areas for processing and disposal. Most of the radionuclides discharged to the ground decay before reaching the river via passage through the soil. Others are absorbed or filtered by soil particles and retained. Although some of these radionuclides eventually enter the river, the total quantity of radioactivity entering the Columbia River from N reactor is a negligibly small fraction of that released from the single-pass reactors, and has generally not been detectable in the river at the downstream plant boundary.

At the older single-pass production reactors, some elements present in the cooling water are activated while passing through the reactors. Other elements adhere to films formed on surfaces of fuel elements and process tubes, are activated, and are eventually discharged with the cooling water to the river. Table 1 shows the relative abundance of the radionuclides found in the cooling water of the older single-pass production reactors, 4 hours after leaving the reactor.

Many of the radionuclides formed in reactor cooling water are short-lived and disappear quickly due to radioactive decay. In addition, sedimentation and uptake by aquatic organisms removes some fraction of most radionuclides from the river water. Small amounts of fission products are released to the river from the fissioning of natural uranium present in the water used for cooling, from occasional element cladding failures, and from weapons test fallout. Some radionuclides probably also entered

Table 1. Relative abundance of reactor effluent radionuclides[a]

Percent of abundance					
Major (90 percent)	Minor (9 percent)	Trace (1 percent)			
^{24}Na	^{32}P	^{3}H	^{90}Sr	^{133}I	[b] ^{147}Pm
^{31}Si	^{46}Sc	^{14}C	^{91}Sr	^{135}I	[b] ^{149}Pm
^{51}Cr	^{69m}Zn	^{35}S	[b] ^{90}Y	^{136}Cs	[b] ^{151}Pm
^{56}Mn	^{72}Ga	^{45}Ca	[b] ^{91}Y	^{137}Cs	[b] ^{152}Eu
^{64}Cu	^{76}As	^{54}Mn	[b] ^{93}Y	^{140}Ba	[b] ^{156}Eu
	^{92}Sr	^{59}Fe	^{95}Nb	[b] ^{141}Ce	[b] ^{153}Gd
	^{122}Sb	^{60}Co	^{99}Mo	[b] ^{143}Ce	[b] ^{159}Gd
	^{132}I	^{65}Ni	^{103}Ru	[b] ^{144}Ce	[b] ^{160}Tb
	[b] ^{140}La	^{65}Zn	^{106}Ru	[b] ^{142}Pr	[b] ^{161}Tb
	[b] ^{152m}Eu	^{87m}Sr	^{124}Sb	[b] ^{143}Pr	[b] ^{166}Ho
	[b] ^{153}Sm	^{89}Sr	^{131}I	[b] ^{147}Nd	[b] ^{169}Er
	[b] ^{165}Dy				[b] ^{171}Er
	^{239}Np				

[a] Trace nuclide composition based on analyses made in 1964 and 1968.
[b] These radionuclides as a group are denoted hereafter as RE+Y (rare earths+yttrium).

the river from ground waste disposal sites, but their contribution to the total radioactivity in the river in 1970 was not detectable.

River flow rates

Seasonal fluctuations in flow rate of the Columbia River affect concentrations of radionuclides released to the river by varying the quantity of water available for dilution. In addition, the scouring of sediments deposited in reservoirs behind each Columbia River dam causes seasonal fluctuations in transport rates of those longer-lived nuclides accumulated in the sediments. The fluctuating flow rate also affects the time required for a specific volume of water to move from one location to another, which in turn affects the time available for decay of the shorter-lived nuclides before exposure to the public.

The weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams are determined from daily average flow rates published by the U.S. Geological Survey (*4*). For 1970, the average river flow rate at Priest Rapids was 2 790 m^3/s (96 400 ft^3/s) which was less than the 1948–1962 annual average of 3 770 m^3/s (133 000 ft^3/s).

River concentrations

During 1970, samples of river water were collected at Vernita upstream from the production reactors and below the reactors at the Richland water plant intake, and at Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. This cumulative sampling technique, however, prevents evaluation of the concentrations of radionuclides with very short half-lives; these were measured in monthly "grab" samples (*2*).

Table 2 shows the annual average radionuclide concentrations of selected radionuclides in river water at Richland and at Bonneville Dam for 1966–1970. The data for 1966 reflect the effects of complete reactor shutdown during July and August. Comparison of 1970 with 1969 concentrations indicates a major reduction for all radionuclides released to the river.

Table 3 shows concentrations for a larger list of nuclides at Richland and Vernita for 1970 only. Activation product nuclides and neptunium–239 are attributed to Hanford reactor operations. Strontium–90, plutonium–239, and total alpha-emitter concentrations are near or below analytical limits, and do not indicate a significant contribution from Hanford by com-

Table 2. Annual average concentrations of selected radionuclides in the Columbia River, 1966–1970

Radionuclide	Concentration (pCi/liter)									
	1966		1967		1968		1969		1970	
	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam
Phosphorus-32	140	23	190	25	92	15	73	14	28	5
Scandium-46	30	NA	60	18	100	20	72	NA	43	NA
Chromium-51	3 600	1 300	3 200	1 400	1 500	530	720	240	300	100
Zinc-65	200	43	220	62	86	<30	72	25	34	10
Iodine-131	18	3	8	3	7.4	<3.2	4.0	NA	<2	NA

NA, no analysis.

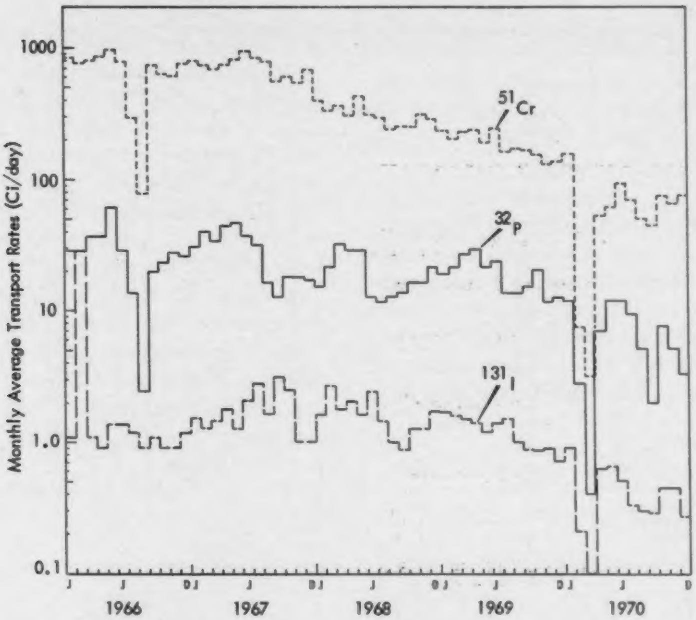


Figure 2. Phosphorous–32, chromium–51, and iodine–131 transport rates in the Columbia River at Richland

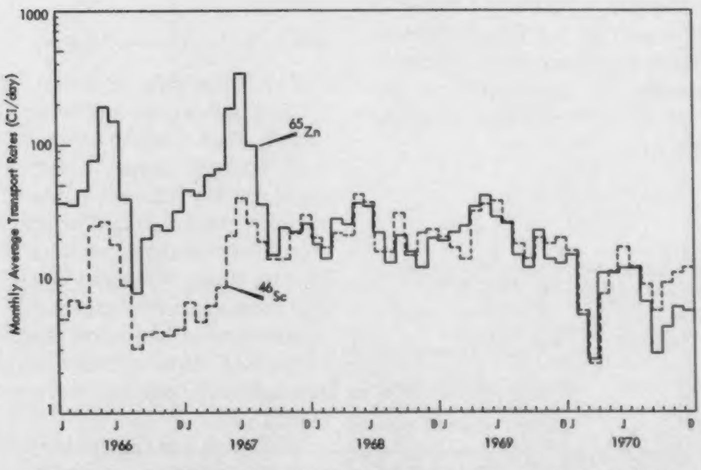


Figure 3. Scandium–46 and zinc–65 transport rates in the Columbia River at Richland

Table 3. Concentrations of radionuclides in the Columbia River at Richland and Vernita, 1970

Radionuclides	Analytical limit (pCi/liter)	Concentration guide (pCi/liter)	Concentration (pCi/liter)									
			Vernita					Richland				
			Number of samples	Maximum	Minimum	Average	Percent of AEC standard	Number of samples	Maximum	Minimum	Average	Percent of AEC standard
Alpha	0.5	[a] 30	12	0.97	(c)	0.59	2.0	12	1.2	(c)	0.60	2.0
Rare earth+yttrium[b]	5	[a] 40 000						5	670	180	340	.9
Hydrogen-3	1 000	3 000 000	12	2 600	(c)	840	.03	12	2 700	(c)	1 100	.04
Sodium-24	35	30 000						23	2 300	60	900	3.0
Phosphorus-32	6	20 000						44	93	9.1	28	.1
Scandium-46	20	40 000						51	120	(c)	43	.1
Chromium-51	70	2 000 000						51	1 200	(c)	300	.02
Manganese-56	50	100 000						5	230	63	100	.1
Copper-64	20	200 000						5	1 500	460	800	.4
Zinc-65	20	100 000						51	99	(c)	34	.03
Arsenic-76	5	20 000						5	180	48	130	.7
Strontium-90	.5	300	12	.61	(c)	.44	.1	12	.7	(c)	(c)	<.2
Antimony-122	5	30 000						5	400	42	120	.4
Iodine-131	2	300						51	5.4	(c)	(c)	<.6
Neptunium-239	10	100 000						5	1 400	320	570	.6
Plutonium-239	.025	5 000	2	(c)	(c)	(c)	.0005	2	(c)	(c)	(c)	<.000

[a] Calculated from isotopic mixture.
[b] Rare earths plus yttrium separation.
[c] Less than the analytical limit.

parison with upstream analyses at Vernita. The small increase in measured tritium concentrations between Vernita and Richland is probably due to releases from the operating reactors. The average concentration of any nuclide in the river at Richland during 1970 did not exceed 3 percent of the AEC standards.

Bonneville Dam, approximately 490 km (240 miles) below the Hanford reactors, is the farthest downstream location where river water is routinely sampled as part of the Hanford environmental surveillance program. Measurements at this location provide an upper limit to the annual transport of specific nuclides into the Pacific Ocean (table 4).

Table 4. Annual average transport rates of selected radionuclides past Bonneville Dam, 1966–1970

Radionuclides	Transport rate (Ci/day)				
	1966	1967	1968	1969	1970
Phosphorus-32	9	12	6.2	7.1	2.3
Scandium-46	NA	10	7.5	NA	NA
Chromium-51	430	610	200	100	40
Zinc-65	21	40	<13	<15	4.7

NA, indicates no routine analysis was made.

Transport rates

Figures 2 and 3 show the river transport rates of several radionuclides past Richland for 1966 through 1970. The transport rates at Richland in 1970 for the five radionuclides shown were significantly lower than the 1969 values. Table 4 shows the annual average transport rates of selected radionuclides past Bonneville Dam.

Trend indicator—whitefish

The Columbia River is popular for sports fishing both above and below the Hanford reservation. Fish feeding downstream from the reactors contain some radionuclides originating from reactor effluent, acquired for the most part through food chains. Phosphorus-32 is the most significant of these nuclides with regard to population doses. Changes in river concentrations and temperatures may induce changes in concentrations in biological media, and the ultimate uptake of radionuclides at each trophic level depends on complex environmental interrelationships.

Whitefish are the sports fish that usually contain the greatest concentration of radioactive materials. Furthermore, they can be caught

during winter months when other sports fish are difficult to sample. Therefore, phosphorus-32 data accumulated from whitefish sampling near the plant boundary are useful as a long-term trend indicator of concentrations in biological media, even though whitefish are not the most significant source of radionuclides for the local fish-consuming population.

Concentrations of phosphorus-32 in whitefish during 1970 tend to follow the same seasonal trends observed in past years. As expected from river concentrations, the average concentration of phosphorus-32 in whitefish sampled downstream from the reactors during 1970 decreased to 17 pCi/g from 34 pCi/g during 1969 (*1*).

Radioactivity in groundwater

Radioactivity in the groundwater beneath the Hanford project results primarily from ground disposal of wastes in the chemical separations areas. These wastes are routed to various facilities, dependent upon their radionuclide burden and chemical content. High-level wastes[4] are stored in underground concrete tanks lined with steel. Intermediate-levels wastes[5] are sent to underground "cribs" (covered liquid waste disposal sites) from which they percolate into the waste disposal and high-level waste storage have soil with good ion exchange capacity and

[4] High-level: >100 mCi/liter.
[5] Intermediate-level: 50 nCi/liter to 100 mCi/liter.

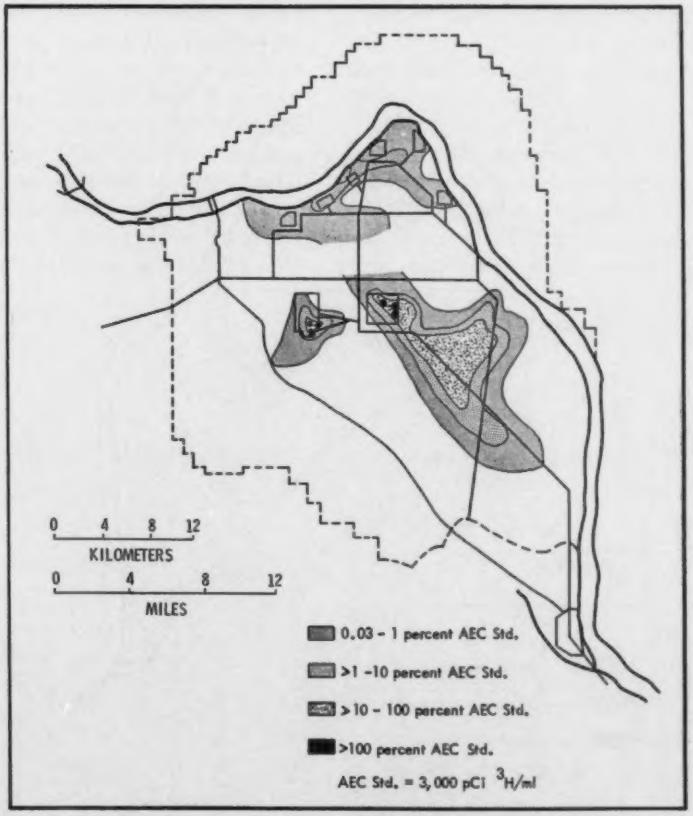


Figure 4. Tritium concentrations in groundwater, Hanford, July–December 1970

groundwater depths of 50 to 100 m. Low-level wastes[6] are usually sent to depressions in the ground where surface ponds or "swamps" have been formed as the result of the continuous addition of relatively large volumes of water.

One important objective in the management of wastes placed in the ground is to prevent radionuclides from reaching the groundwater in quantities that could cause significant human radiation exposure should they ultimately migrate to the Columbia River. An extensive groundwater surveillance program is maintained at Hanford to aid in achieving this objective. Hundreds of wells have been drilled at various locations around the Hanford project, including sites within and near ground disposal and tank storage areas, to monitor the movement of radionuclides in the groundwater.

The radioactivity reaching the groundwater from the chemical separations areas is primarily tritium and ruthenium–106; cobalt–60, and technetium–99 have also been found but at much lower concentrations. The more radiotoxic nuclides, such as strontium–90, have not been detected in groundwater except in the immediate vicinity of a few specific disposal sites.

Figures 4 and 5 show the probable extent of detectable tritium and ruthenium–106 in groundwater beneath the Hanford project as of December 31, 1970 (*5*). The outer boundary of the contamination contours, i.e., 0.03 percent of the AEC standard for tritium and 2 percent of the AEC standard for ruthenium–106, repre-

[6] Low-level: <50 nCi/liter.

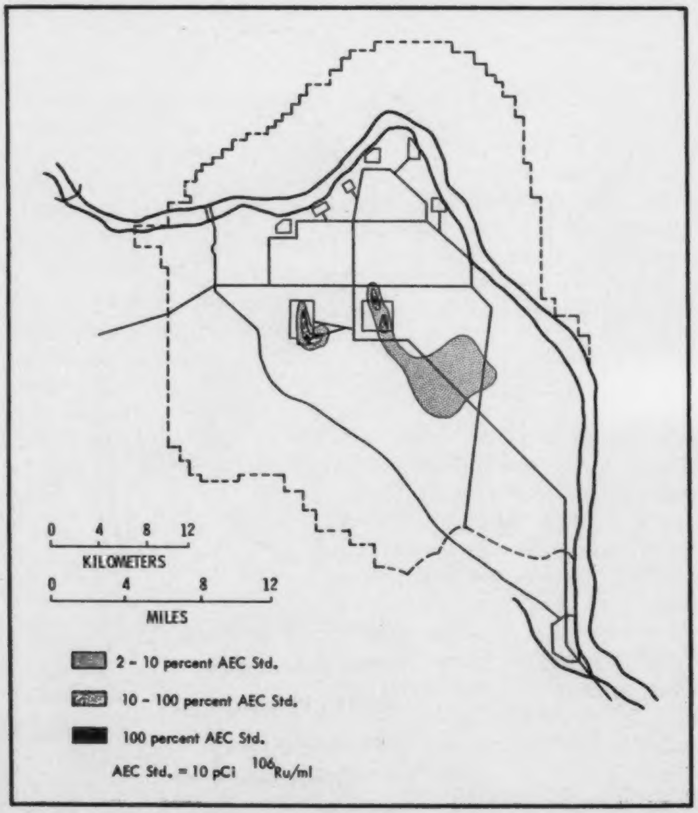


Figure 5. Ruthenium–106 concentrations in ground water, Hanford, July–December 1970

sent the detection levels routinely achievable for those radionuclides.

It is possible that some radionuclides from the chemical processing areas are presently entering the Columbia River. However, the concentrations of these nuclides are too small to be routinely measurable in the groundwater near the river or in the river itself, and any radiation dose from them is negligible.

Tritium in the groundwater near the river in the vicinity of the N reactor area may have contributed to the small increase in tritium concentration observed in the river between Vernita and Richland in 1970 (table 3), but any resulting dose from offsite drinking water would still be negligible.

A remote possibility exists that radioactive or process materials could penetrate to confined aquifers which generally underlie the Pasco Basin. Several farm wells on the east side of the Columbia River, which are believed to penetrate to those confined aquifers, are routinely sampled for tritium and nitrate ion. The data are not definitive, since contamination from the surface by nitrate from fertilizers and tritium from non-Hanford sources in recent precipitation can also occur. Samples from all five offsite wells during 1970 were at or less than the analytical limit for tritium and nitrate ion.

Radioactivity in drinking water

The city of Richland, about 75 km (47 miles) downstream from the Hanford reactors, is the first community below the project that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few kilometers farther downstream, also use the river as a water source. The Richland and Pasco water plants use a modern flocculation-filtration treatment method; water for Kennewick is pumped from Ranney well collectors (infiltration pipes) laid in the riverbank.

During 1970, cumulative and periodic grab water samples were collected at both the Richland and Pasco water plants and analyzed for selected individual radionuclides and gross beta activity (table 5). The Pasco sampling was discontinued at midyear since the calculated doserate from drinking water was uniformly less than at Richland and was becoming less and less significant. At each plant, water was sampled after treatment and just prior to entering the city distribution system.

The concentrations of short-lived radionuclides in the water at the time it is consumed were less than shown in table 5 because there is a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending

Table 5. Concentrations of several radionuclides in Richland drinking water,[a] 1970

Radionuclide	Number of samples	Concentration (pCi/liter)			Percent of AEC standard
		Analytical limit	Richland	AEC standard	
Total beta (counts per min/ml)	95	0.2	1.0	[b] 2 000 000	<0.1
Sodium-24	9	35	640	30 000	2.1
Phosphorus-32[c]	52	6	16	20 000	<.1
Chromium-51	4	70	410	2 000 000	<.1
Zinc-65	52	20	20	100 000	<.1
Arsenic-76	4	5	41	20 000	.2
Antimony-122	4	5	42	30 000	.1
Iodine-131[c]	52	2	2.0	300	.7
Iodine-133	9	10	13	1 000	1.3
Neptunium-239	9	10	220	100 000	.2
Rare earths + yttrium[d]	4	5	26	[b] 45 000	<.1

[a] Measured at the water plants.
[b] Calculated from isotopic ratios.
[c] Results based on cumulative samples.
[d] Rare earths plus yttrium fraction.

upon the location of the customers on the distribution system and the water demand.

The nuclide showing the largest average percentage of the AEC standard in Richland drinking water during 1970 was sodium–24, about 2 percent.

Annual average concentrations of radionuclides measured at the Richland water plant were used to calculate the doses from drinking water for comparison with past years. The correlation between the GI tract dose rate at the water plant (established by direct measurement of individual radionuclide concentrations) and the gross beta activity was determined monthly. This correlation, used in conjunction with thrice-weekly measurements of gross beta activity at the water plant, provided the basis for estimation of the GI tract dose. The estimated annual GI tract dose to Richland residents from the measured radionuclides in drinking water continued to decrease in 1970 (10 mrem) from 1969 (17 mrem).

Radionuclides in Columbia River fish

The quantities and kinds of fish caught by local fishermen have been previously estimated from surveys carried out from 1961 to 1965 in cooperation with the Washington State Game Department. The maximum estimate of consumption by the fishermen interviewed was 200 meals per year of panfish species (crappie, perch, and bass) taken from the Columbia River. Additional dietary data collected during 1966 and 1967 from household questionnaires and interview surveys also showed individual consumption estimates as high as 200 meals of fish per year (*6*). The primary fishing locations for the catch of these fish were Burbank, Hover-Finley, and Island View. The average percentage of the maximum annual consumption by species was 73 percent crappie, 16 percent bass, and 11 percent perch. Based on data collected during 1970, the average concentration of phosphorus–32 in such a mixture of panfish was about 5 pCi/g, and that of zinc–65 was 2 pCi/g. Gamma scans of samples showed no other radionuclides present on the average above the analytical level.

From this species distribution and radiochemical analyses of the specimens collected, the "maximum individual's" estimated intakes during 1970 were 0.20 μCi of phosphorus–32 and 0.08 μCi of zinc–65 (*1*) or less than one-half the corresponding intakes during 1969. The calculated dose to the bone of the "maximum individual" for 1970 from this source was 38 mrem or about 2.5 percent of the standard of 1 500 mrem per year.

The average consumption of Columbia River fish by Richland residents was estimated from diet questionnaires completed by Hanford plant employees (*3*). Assuming the same mixture of species as for the maximum individual, the average Richland resident's intake during 1970 was estimated to be 0.002 μCi phosphorus–32 and 0.001 μCi zinc–65. These intakes correspond to a bone dose of about 0.5 mrem or about 0.1 percent of the standard of 500 mrem per year for the population average.

Radioactivity in shellfish

Zinc–65 and phosphorus–32 are the only radionuclides from Hanford reactor effluents that have been found in sufficient abundance in seafoods collected beyond the mouth of the Columbia River to be of significance to human radiation exposure. Oysters have been found to contain higher concentrations of zinc–65 than other common seafoods (*3*). Oyster samples were obtained during 1970 from commercial sources at Willapa Bay, Wash. This area is a major regional commercial source of oysters and, because of prevailing ocean currents, a likely location for maximum concentrations of Hanford nuclides in shellfish.

Monthly average concentrations of phosphorus–32 and zinc–65 were periodically measured in oysters grown commercially in the Willapa Bay area. A normal seasonal minimum for phosphorus–32 occurs in the late summer. The zinc–65 data for 1970 show a decrease through the year approximating the radioactive half-life. The annual average concentrations for 1970 were 0.13 pCi/g of zinc–65 and 0.06 pCi/g of phosphorus–32.

Fresh shellfish are not an important item in the average tri-cities diet, but residents of some coastal areas may consume more than the refer-

ence value of 50 g/day (*7*). For such individuals, shellfish are assumed to be their only source of radionuclides of Hanford origin. Consumption of oysters containing the 1970 average concentrations of phosphorus–32 and zinc–65 at the rate of 50 g/day would result in annual doses of about 2.5 mrem to the GI tract, 1.6 mrem to the whole body, and 2.9 mrem to the bone of a standard man (*8*). This calculated whole body dose is about 0.3 percent of the appropriate dose standard of 500 mrem per year.

Radionuclides in game birds

Waterfowl and other gamebirds utilizing the river downstream from the reactors or open low-level waste disposal sites within the plant boundaries may ingest phosphorus–32, zinc–65, and other radionuclides with their intake of insects, algae, vegetation, and water containing these radionuclides. Although the spring and fall migrations bring a temporary influx of great numbers (up to 200 000 birds), some waterfowl remain in this general area throughout the year. The river also provides cover, food, and water for a local population of pheasant, quail, and other upland gamebirds. The concentrations of radionuclides in the flesh of gamebirds at the time of consumption are dependent upon the bird species, the geographical locations from which the birds are taken, their residence time in the vicinity, their current feeding habits, and the elapsed time between killing and consumption of the birds.

Table 6 shows radionuclide concentrations in the muscle (the edible portion) of gamebirds collected along the river within the Hanford project for the environmental monitoring program during hunting seasons in 1970. The maximum concentration in such birds during 1970 was 170 pCi ^{32}P/g, for comparison, the maximum observed in 1969 was 510 pCi ^{32}P/g for birds collected in the same area.

Data from a dietary survey of Hanford employees (*3*), from a special survey of local hunters (*6*), and from the radionuclide concentration data for the various species have been combined to estimate the species mix and the radionuclide content of an average local gamebird meal. About 30 percent of the gamebird meals consumed by local hunters were reported to be birds shot within about 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. Past analyses have shown that pheasants collected beyond this distance contain little, if any, radioactivity of Hanford origin. About 44 percent of all birds eaten were reported to have been placed in frozen storage, which would permit appreciable decay of any phosphorus–32 before consumption.

The maximum total gamebird consumption by adults reported to date is 100 meals per year, or an estimated 32 kg/yr. Consumption of this weight of the "average gamebird meal" (table 7) would result in intakes of 0.022 μCi of phosphorus–32 and 0.014 μCi of zinc–65, implying a dose of 4.2 mrem to the skeleton, or less than 0.4 percent of the standard for individual members of the population. Consumption of 1.24 kg/yr, the estimated annual intake for the "average" Richland resident, would result in a total dose of about 0.2 mrem to the skeleton, less than 0.1 percent of the appropriate standard of 500 mrem/yr.

Table 6. Radionuclide concentrations in game birds, 1970

Species	Number of samples	Concentration (pCi/g)											
		Phosphorus-32			Cobalt-60			Zinc-65			Cesium-137		
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Geese [a] (river)	18	49	([c])	13	150	([c])	8.3	9.0	0.23	3.2	0.31	([c])	0.14
Duck [a] (river)	79	170	([c])	7.1	.16	([c])	([c])	9.2	([c])	1.6	.25	([c])	.04
Pheasant [b]	34	26	([c])	3.1	.41	([c])	([c])	8.4	([c])	2.1	.31	([c])	.09
Quail [b]	23	17	([c])	2.0	([c])	([c])	([c])	4.0	([c])	1.0	2.4	([c])	.18
Analytical limit			1.0			0.15			0.2			0.1	

[a] Collected on the Columbia River within the Hanford boundary.
[b] Collected within 5 km (3 miles) of the Columbia River and within the Hanford boundary.
[c] Less than the analytical detection limit.

Table 7. Contribution[a] of each species to 100 grams of an average game bird meal, 1970

Species	Weight (grams)	Radionuclide content (pCi)	
		Phosphorus–32	Zinc–65
Duck	23	46	10
Goose	6	16	10
Quail	12	5	2
Pheasant	47	26	36
Grouse	13	2	1
Total	100	95	59

[a] Weighted for location of kill by using measured concentrations for river birds and assuming no phosphorus–32 or zinc–65 in other birds. Also weighted for frozen storage by assuming complete decay of phosphorus–32 but no significant decay of zinc–65 during frozen storage of 44 percent of the birds.

The dose calculations shown above do not include four ducks collected at the K and N reactor area trenches between the last week in December 1969 and the first week in March 1970. Muscle tissue from these four birds, of 15 collected at these locations during this period, showed concentrations from 0.03 to 0.14 μCi ^{32}P/g, compared to a maximum in birds collected along the river of 0.000 17 μCi ^{32}P/g. Analysis of gizzard contents indicated some feeding on filamentous algae present in the water in the trenches. Steps were taken to prevent further access by waterfowl, including partial backfilling and screening the remaining open areas of the trenches.

Immediate consumption of 230 g (one-half pound—a normal meal) of flesh with the highest concentration, with consequent ingestion of about 30 μCi of phosphorus–32, would have resulted in a calculated skeletal-bone dose to an adult of about 6 rem, four times the applicable annual dose standard. The associated whole body dose, including a contribution from zinc–65, would have been about 250 mrem, or about 15 percent of the applicable annual dose standard.

Even were such a bird to be shot by a hunter, delays between the time a bird left a trench and the time of shooting, and as a result of the frequent practice of freezing gamebirds for later consumption would have permitted significant radioactive decay. This would further reduce the probability of consuming flesh containing the higher concentrations of phosphorus–32. For the bird with the maximum concentration that has been considered here, any delays in consumption of more than 4 weeks would have reduced the skeletal bone dose to less than 1 500 mrem (the annual standard).

The consumption of such a bird by any member of the public, however, is considered highly improbable in view of the facts that: (a) very few birds (out of some 200 000 in the area at that time) would have been likely to spend sufficient time on the trenches near the reactor areas to accumulate such large amounts of radioactive materials, and (b) concentrations of this magnitude have never been found in hundreds of birds sampled along the river for over 20 years. In our judgment, ducks collected on swamps, trenches, or ponds are not representative of those available to the general population, and dose estimates derived therefrom are not pertinent for inclusion in comparisons with the established dose standards.

Radioactivity in milk and produce

Irrigation with river water containing radionuclides can contribute radioactivity to local milk and locally-grown farm produce, as can deposition of airborne materials from weapons test fallout and from Hanford sources. Chemical separations facilities would generally be the principal local source of airborne radionuclides other than fallout, although unusual radioactivity releases could occur from ventilation stacks of reactor or laboratory facilities.

The farming area closest to the separations facilities is at Ringold about 21 km (13 miles) away. Much of the land east and south of the project boundary is under cultivation and may be in the path of airborne releases. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactors are the Ringold farms and the Riverview district west of Pasco. These are 40 and 65 km (25 and 40 miles), respectively, downstream from the operating reactors.

The milk surveillance program maintained during 1970 included samples from local farms and dairies and from commercial supplies avail-

Table 8. Radionuclide concentrations in local milk, 1970

Location	Radionuclide concentration[a] (pCi/liter)																		
	Iodine–131				Phosphorus–32					Zinc–65			Strontium–90				Cesium–137		
	Number of samples	Maximum	Average	Percent of AEC standard	Number of samples	Maximum	Average	Percent of AEC standard	Number of samples	Maximum	Average	Percent of AEC standard	Maximum	Minimum	Average	Percent of AEC standard	Maximum	Average	Percent of AEC standard
Riverview	52	3.6	0.84	0.3	52	1 200	210	1	52	300	120	0.1	9.1	2.9	5.0	1.6	49	7.8	<0.1
Benton City & West Richland composite	62	10	1.3	.4					39	60	28	<.1					25	5.8	<.1
Benton City	11	3.2	1.2	.4					11	82	50	<.1	4.6	3.5	4.1	1.3	27	18	<.1
Columbia Basin composite No. 2	27	2.5	1.1	.4	27	74	23	.1	27	64	32	<.1	4.6	ND	2.2	.7	31	7.2	<.1
Columbia Basin composite No. 3	88	4.4	.92	.3					38	83	36	<.1					44	9.7	<.1
Commercial	56	21	.83	.3					24	77	35	<.1	9.5	ND	3.6	1.2	34	14	<.1
AEC standard	300				20 000				100 000				300				20 000		
Analytical limit	2				6				50				2				30		

[a] Where no minimum value is shown, all minimum values were less than the analytical limit.
ND, less than the analytical limit.

able to people in the tri-cities. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus–32 and zinc–65 as well as fission products from fallout and possibly Hanford sources. Commercial milk distributed in the tri-cities normally does not contain detectable phosphorus–32 and zinc–65, because only a small fraction of the milk is produced on farms irrigated with water drawn from the Columbia River below the Hanford reactors.

Table 8 gives concentrations for an expanded list of radionuclides in milk and table 9 gives produce for 1970. During 1970, the annual average concentrations of phosphorus–32 and zinc–65 for the Riverview farm were 210 and 120 pCi/liter compared to 1969 averages of 160 and 110 pCi/liter, respectively, for the same farm. Seasonal fluctuations in concentrations of both phosphorus–32 and zinc–65, caused primarily by irrigation and feeding practices, followed expected trends. Adult residents consuming milk (1 liter/day) obtained from the Riverview area could have received an annual dose from phosphorus–32 and zinc–65 of about 15 mrem to the bone (1 percent of the applicable dose standard).

Iodine–131 concentrations in both farm milk and commercial milk during 1970, were consistently less than the analytical limit of 2 pCi/liter. The maximum iodine–131 concentration of 21 pCi/liter for the period was measured in a sample of commercial milk collected in December and was attributed to atmospheric weapons testing.

The concentrations of other fallout nuclides, strontium–90 and cesium–137, in the local environs are usually below the national average because of the low rainfall. Concentrations of strontium–90 in locally produced farm and commercial milk (table 8) were similar in 1970 to those in commercial milk produced in other areas remote from the Hanford plant.

Fresh produce, meat, and eggs from local sources were sampled periodically for radioanalysis during the 1970 growing season and compared with samples from commercial sources. Results of these measurements were lower than those of previous years as expected, and indicated that only small quantities of

Table 9. Radionuclide concentrations in local foods, 1970

Foodstuffs	Radionuclide concentration ᵃ (pCi/g)												
	Phosphorus-32			Number of samples	Zinc-65			Strontium-89		Strontium-90			
	Number of samples	Maximum	Average		Maximum	Minimum	Average	Maximum	Average	Maximum	Minimum	Average
Farm meat	5	2.5	1.6	8	4.6	.5	2.4	--------	--------			
Commercial meat	13	2.0	.31	27	.12	ND	.04	--------	--------	0.013	ND	0.005
Commercial poultry	--------	--------	--------	1	ND	ND	ND					
Farm poultry	7	.22	.08	7	1.0	ND	.55	ND	ND	ND	ND	ND
Commercial eggs	--------	--------	--------	4	.042	ND	ND					
Farm eggs	16	5.6	1.2	16	2.5	ND	.54	0.011	0.006	.002	ND	.0015
Farm fruit	9	.15	.036	11	.14	ND	.078	--------	--------	.025	ND	.008
Farm leafy vegetables	7	.49	.28	9	.60	ND	.28	.004	.003	.06	0.01	.039
Farm other vegetables	9	.18	.06	11	.21	ND	.09	--------	--------	.68	.005	.13
Commercial leafy vegetables	6	.49	.12	6	.12	ND	ND	.033	.012	.031	ND	.017
Commercial fruit and vegetable composite	4	.07	ND	4	.12	.06	.09	--------	--------	.008	.006	.006
Analytical limit	1.0			0.05				0.02		0.002		

Foodstuffs	Number of samples	Zirconium-niobium-95		Ruthenium-106		Iodine-131		Cesium-137		Cerium-praseodymium-144	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Farm meat	8	0.04	0.01	ND	ND	ND	ND	0.04	0.02	ND	ND
Commercial meat	27	ND	ND	ND	ND	ND	ND	.066	.027	ND	ND
Commercial poultry	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Farm poultry	7	ND	ND	ND	ND	ND	ND	.038	.020	ND	ND
Commercial eggs	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Farm eggs	16	ND	ND	ND	ND	ND	ND	.025	ND	ND	ND
Farm fruit	11	.025	ND	ND	ND	ND	ND	.036	.013	ND	ND
Farm leafy vegetables	9	.71	.16	0.89	0.17	0.41	0.04	.170	.056	1.3	0.41
Farm other vegetables	11	ND	ND	ND	ND	ND	ND	.062	.011	ND	ND
Commercial leafy vegetables	6	.26	.06	ND	ND	ND	ND	ND	ND	ND	ND
Commercial fruit and vegetable composite	4	ND	ND	ND	ND	ND	ND	.038	ND	ND	ND
Analytical limit		0.03		0.6		0.05		0.02		1.0	

ᵃ Where no minimum value is shown, all minimum values were less than the analytical limit.
ND, less than the analytical limit.

radionuclides from Hanford were present in locally-grown produce. However, a resident of a local farm, consuming eggs and one-half pound of beef per day raised on pasture irrigated with water taken from the river downstream from the reactors, could have received a bone dose up to 30 mrem for the year, 2 percent of the applicable standard.

Radioactivity in the atmosphere

Gaseous effluents from the Hanford chemical separations facilities are released to the atmosphere through tall stacks after passage through high-efficiency filters. Laboratory stacks, reactor-building stacks, and stacks from waste storage facilities may also release small amounts of particulate radioactive materials. The reactors release some noble gases, mostly argon–41, to the atmosphere under normal operating conditions.

During 1970, measurements of airborne iodine–131, gross beta, and total alpha were routinely made at 23 locations offsite and around the Hanford reservation boundary; locations are shown in figure 6. Airborne data concentrations followed the annual cycle observed in previous years and showed about the same maximum and minimum values as for 1969.

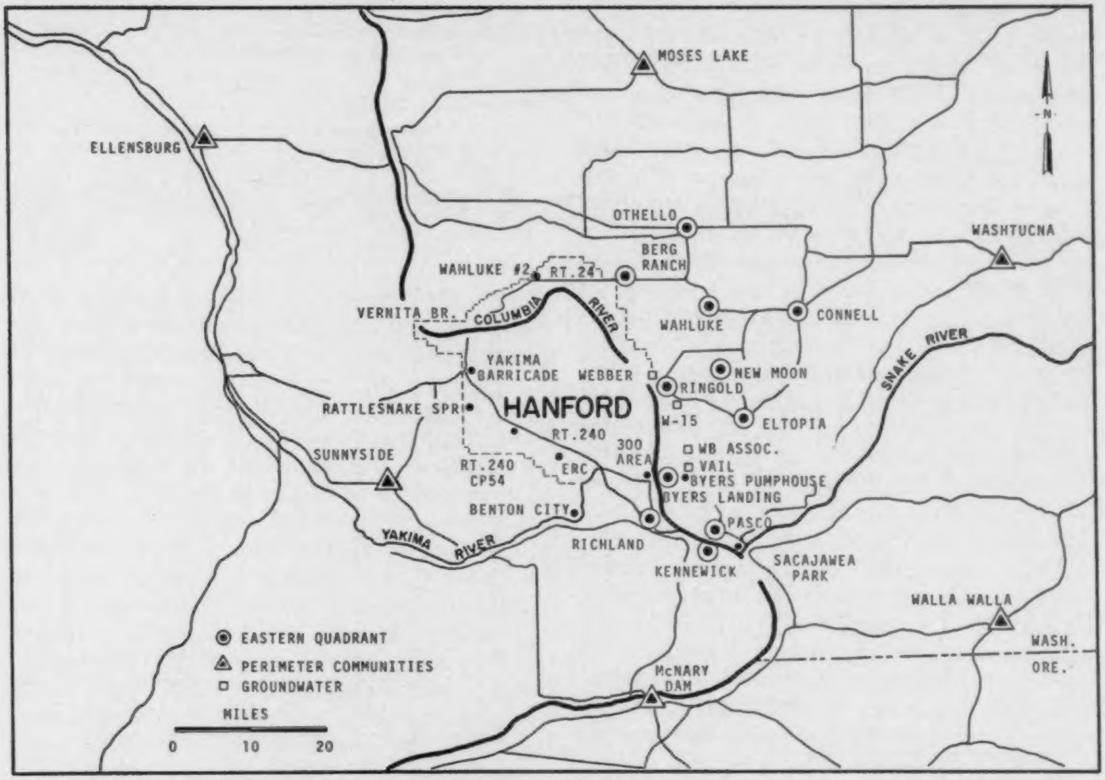


Figure 6. Offsite air sampling locations

Tables 10 and 11 present a more detailed review of the 1970 airborne radioactivity data. Analyses for strontium-90 and total plutonium alpha were made quarterly on composited filters from several locations. The results are given in table 11, with average total alpha and gross beta concentrations for comparison. Locations within each group are given in table 10. The data show that plutonium alpha accounted for less than 1 percent of the total alpha activity and strontium-90 for about 2 percent of the gross beta activity. The radioactivity measured is believed to be essentially all of natural origin or from regional fallout.

Insufficient isotopic data were available to determine appropriate AEC standards for gross alpha and beta. However, the average airborne total alpha and gross beta concentrations at the Hanford boundary locations were the same as the average at more distant sampling locations, indicating that Hanford operations did not contribute measurably to offsite airborne radioactivity.

External radiation

Land measurements

Prior to June 1970, ionization chambers (100 ml nominal volume) were used at a limited number of locations for basic gamma radiation measurements. Pocket ionization chambers (gamma pencils) were also used at all air sampler locations in order to distinguish major changes in gamma radiation levels. Table 12 shows measurements of an onsite and offsite location over a 5-year period. The upward trend is believed to be due to increased deposition

Table 10. Radioactivity in air, 1970

Location	Total alpha (pCi/m³)				Total beta (pCi/m³)			Iodine-131 (pCi/m³)							
								January-June 1970				July-December 1970			
	Number of samples	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Percent of AEC standard	Maximum	Minimum	Average	Percent of AEC standard
Southeast quadrant:															
Berg Ranch	39	0.042	0.001	0.011	0.99	0.05	0.27	0.029	ND	0.011	0.01	0.39	ND	0.12	0.1
Wahluke Watermaster	13	NA			0.84	.10	[a].31					.28	ND	.096	.1
Wahluke Slope #2	21	NA			1.1	.03	.41	([a])	ND	.010	.01				
New Moon	39	.032	.003	[a].010	.88	.03	.26	.051	ND	.012	.01	.25	ND	.048	.05
Eltopia	39	NA			1.0	.03	.34								
Ringold	39	.027	.001	.011	1.3	.06	.31	.45	ND	.016	.02	.26	ND	.10	.1
Byers Landing	39	.038	.001	.012	1.4	.02	.35	.033	ND	.008	.01	.21	ND	.059	.06
Richland	39	.044	.001	.013	1.3	.06	.37	.026	ND	.007	.01	.18	ND	.068	.07
Pasco	39	.045	.005	[a].016	1.3	.02	.37	.026	ND	.009	.01	.16	ND	.076	.08
Kennewick	12	.039	.002	.014	.50	.02	[a].23					.12	ND	.029	.03
Benton City	39	.046	.001	.012	.92	.04	.32	.028	ND	.009	.01	.12	ND	.043	.04
Southeast quadrant average				.012			.32			.010				.071	.07
Perimeter communities:															
Walla Walla	39	.078	.002	[a].018	1.5	.03	.33								
McNary Dam	39	NA			1.0	.06	.33								
Washtucna	37	NA			1.2	.02	.38								
Moses Lake	31	NA			1.0	.02	.31								
Ellensburg	26	NA			1.2	.04	.21								
Sunnyside	41	NA			1.0	.01	.33								
Othello	13	.033	.002	[a].014	.54	.02	[a].26								
Connell	11	NA			.57	.06	[a].24								
Perimeter average				.016			.30								
Analytical limit		0.001				0.02				0.02				0.07	
AEC standard									100				100		

[a] Six months of data only.
ND, less than the analytical limit.
NA, no analysis.

Table 11. Radioactivity in air, quarterly average, 1970

Location and date	Concentration (pCi/m³)					
	Average gross beta	Strontium-90	Percent of AEC standard	Average total alpha	Plutonium alpha	Percent of AEC standard
Southeast quadrant:						
Jan-Mar	0.15	NA		0.004	NA	
Apr-June	.48	NA		.017	NA	
July-Sept	.52	0.005	0.05	.021	0.000 04	0.2
Oct-Dec	.15	.0027	.03	.009	.000 03	.15
Annual or 6-month average	.32	.004	.04	.014	.000 035	.2
Perimeter communities:						
Jan-Mar	.14	NA		NA	NA	
Apr-June	.50	NA		NA	NA	
July-Sept	.44	.015	.15	.017	.000 03	.15
Oct-Dec	.15	.001	.01	.014	.000 04	.2
Annual or 6-month average	.31	.008	.08	.015	.000 035	.2
AEC standard	100	10		0.03	0.02	

NA, no analysis.

Table 12. Average external radiation exposure rates 1966–1970

Location	Exposure rate (mR/day)				
	1966	1967	1968	1969	1970
Hanford test location	0.35	0.35	0.36	0.37	0.39
Richland	.28	.26	.28	.30	.34

from weapons test fallout, as essentially all of the population exposure at Richland is from natural background and worldwide fallout from nuclear testing.

The chambers, however, have a limited response range (2 mR), and are prone to erroneous readings from mechanical shock, moisture, and dust. The best estimates of environmental gamma radiation dose based on chamber readings are, therefore, apt to be high. In June 1970, thermoluminescent dosimeters (TLD–200)[7] in an experimental shielded package, were installed at all air sampling locations to measure the gamma radiation exposure at 1 meter above ground level. Table 13 shows the average exposure rates for the same location groups used in table 10, the perimeter communities being the most distant locations. The difference of 0.01 mR/day between the two location groups is not statistically significant. The indicated annual exposure of about 60 mR/year implied by the data in table 13 is believed to be low, but the data are considered valid for comparative purposes.

Table 13. Average external radiation exposure rates TLD, July-December 1970

Location	Exposure rate (mR/day)		
	Maximum	Minimum	Average
Perimeter communities	0.32	0.10	0.16
Southeast quadrant	.24	.11	.17

Columbia River shoreline

Estimates of the external radiation dose received from recreational use of the Columbia River shoreline in the vicinity of the Hanford project have been based on routine measurements along the shoreline at Vernita (upstream from the reactor), at Richland, and at Sacajawea Park (where the Snake River enters the Columbia). The exposure rate measured at the shoreline may include components from radioactivity accumulated in sediment deposits and algae growth at the river's edge as well as from any radioactive material in the water. The average exposure rates at the three shoreline locations were measured with a 40-liter ionization chamber, 1 meter back from the water's edge and centered 1 meter above the ground; this approximates the dose rate to the gonads of a person standing on the riverbank. Average shoreline exposure rates (table 14) at these two locations were 0.43 mR/day at Richland and 0.53 mR/day at Sacajawea Park, or 160 and 190 mR/yr, respectively. The average exposure rate at Vernita, upstream of the Hanford plant, was 0.38 mR/day, indicating a small dose increment from Hanford. The maximum recreational user of the river is estimated from local fishermen interviews to spend not more than 500 hours per year along the river shoreline (*6*).

Table 14. Gamma exposure rates at the Columbia River shoreline, 1970

Location	Exposure rate (mR/day)			Exposure rate (mR/year)
	Maximum	Minimum	Average	Average
Vernita	0.98	0.24	0.38	140
Richland	.86	.14	.43	160
Sacajawea Park	1.0	.31	.53	190

Immersion dose

The immersion dose received by tri-city swimmers is based on April through October exposure rates at Richland. Thermoluminescent dosimeters, positioned about 1 meter below the surface of the Columbia River, were substituted for pocket ionization chambers beginning in June 1970. Measured immersion exposure rates were due to gamma emitters in the river from all sources, including Hanford reactors. In the

[7] Harshaw Chemical Company, CaF_2 (Dy).

vicinity of Richland, the average measured immersion exposure rate for 1970 was 0.42 mR/day. For comparison, the immersion exposure rate measured upstream at Vernita was 0.16 mR/day.

Teenagers are the major recreational users of the Columbia River locally. A survey of 430 Richland teenagers in 1968 indicated an average exposure time of about 115 hours in or along the river for members of this group. About one-third of the time was probably immersion and about two-thirds was shoreline exposure (*10*). Using the annual average shoreline exposure rate and the April through October average immersion exposure rate at Richland, the average exposure to the teenage population was estimated to be about 2.1 mR during 1970.

The average whole body dose received by the Richland population from recreational use of the Columbia River can be estimated by assuming that other age groups use the river less than teenagers, but with the same proportion of immersion and shoreline exposure times. For the average exposure of the Richland population, an annual Columbia River (recreation) time of 32 hours was assumed (*10*). Based on 11 hours of immersion and 21 hours of shoreline exposure in the vicinity of Richland, the whole body dose received by the "average" Richland resident during 1970 was estimated to be less than 0.6 mrem.

Surface measurements

Roads and land surfaces in the vicinity of Hanford were periodically surveyed for possible radionuclide deposition resulting from Hanford operations. Eleven small areas, called control plots, are located around the Hanford boundaries. These plots, measuring 3 m $\times$ 3 m (10 feet $\times$ 10 feet), were surveyed monthly or semimonthly with a GM survey meter for deposited radioactive material. No surface radioactivity of Hanford origin was detected on the control plots during 1970.

Public Highway 240, which traverses the Hanford reservation, was surveyed monthly with a bioplastic scintillation detector attached to the bumper of a truck positioned about 0.6 m (2 feet) above the edge of the road surface. This road monitor has been described in document BNWL–62 (*11*). During 1970, no radioactivity was detected by these surveys.

Aerial surveys can be used to detect contamination which is spread over a large area. Like road and control plot surveys, aerial surveys are only quantitative in nature, but through routine use of this technique, a capability for rapid assessment of an emergency situation is maintained. Aerial surveys at Hanford are conducted at an altitude of 150 m (500 feet) using a 3-inch by 5-inch thallium-activated sodium iodide scintillation crystal detector. Aerial survey flight patterns used during 1970 were:

1. near the Hanford project perimeter,
2. 15 to 40 miles beyond the project perimeter, and
3. following the Columbia River from the Vernita Bridge (upstream of the Hanford reactors) downstream to McNary Dam.

During 1970, no significant changes were seen in previously observed patterns.

Fallout from nuclear weapons tests

Measurements of fallout radiation, like measurements of natural background radiation, are all of interest for comparison with the radiation doses resulting from Hanford operations. Dose increments received by residents of the Hanford environs from the fallout nuclides tritium, strontium–90, and cesium–137 have been estimated routinely although they are not included in the assessment of dose attributable to Hanford operations. The concentrations of fallout nuclides in the local environs are below the national average because of the low rainfall.

Several positive analyses for iodine–131 concentrations in milk samples during 1970 were attributed to fallout from weapons testing. Estimates of fallout tritium intakes from drinking water were based on upstream concentrations measured in river water (table 3). Concentrations of strontium–90 and cesium–137 in locally produced farm and commercial milk (tables 8 and 9) were similar to those in commercial milk produced in areas remote from the Hanford plant (*12*), and worldwide fallout was assumed to be the sole source of strontium–90 and cesium–137 in milk.

Assuming that 40 percent of an individual's total strontium–90 intake is obtained from milk (*13*), the intake of strontium–90 for 1970 was estimated to be 5.1 nCi for the "maximum" individual and 1.2 nCi for the "average" Richland resident. The total intake of cesium–137 during 1970 was about 22 nCi for the "maximum" individual and 5.2 nCi for the "average" Richland resident.

Table 15 shows a summary of the estimated annual dose commitments from fallout nuclides present in the Hanford environs in 1970. The estimated strontium–90 annual intake for the "maximum" individual and for the "average" adult Richland resident, evaluated in terms of the Federal Radiation Council guides (*16*), both correspond to 2 percent of the upper end of Range II (200 pCi/day for the average intake by a suitable sample of the exposed population and 600 pCi/day for individuals).

Table 15. Radiation dose commitments[a] from ingestion of individual fallout nuclides, 1970

Organ	Dose (mrem)			
	Tritium	Strontium–90	Cesium–137	Total
Maximum individual:				
Bone	NA	[b] 49	1.6	51
Whole body	<1	[b] 4.6	[c] <1	5
GI tract	NA	<1	<1	<1
Average adult Richland resident:				
Bone	NA	[b] 12	<1	12
Whole body	<1	[b] 1.1	[c] <1	1
GI tract	NA	<1	<1	<1

[a] Not included in dose summaries presented elsewhere.
[b] The radiation dose commitments shown for bone and whole body represent the dose received over a period of 50 years based on ICRP methods (*8, 14*). Only a few percent of the total dose commitment from strontium–90 intake is received during the first year for each of these organs.
[c] For the whole body dose commitment from ingestion of cesium–137 by an adult, the FRC dose conversion factor of 0.06 rem/μCi was used (*15*).
NA, no analysis.

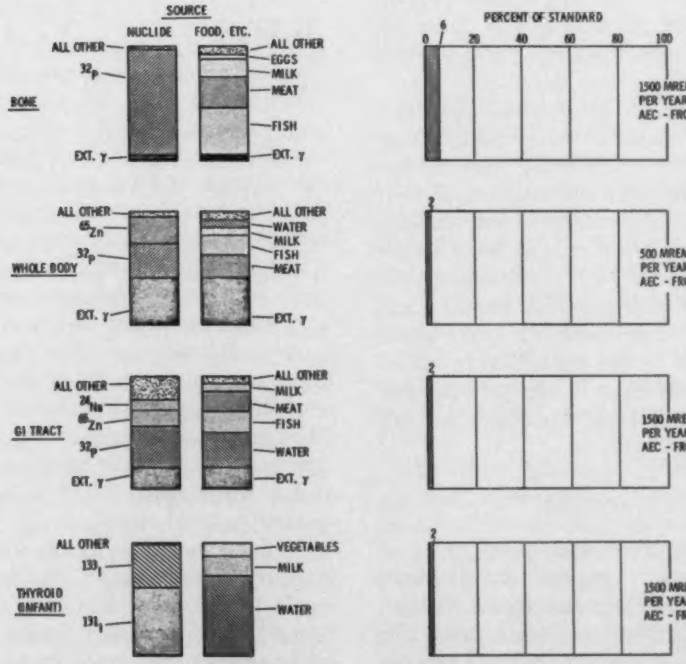


Figure 7. Estimated doses to the "maximum" individual, 1970

Composite estimates of radiation dose

The "maximum" individual

Exposure accumulated from the environmental surveillance program and associated research studies has indicated that those individuals receiving the greatest percentage of permissible radiation dose standards from Hanford sources consumed some combination of the following: fish caught locally in the Columbia River, gamebirds shot near the river, foodstuffs produced on local farms irrigated with Columbia River water drawn from below the reactors, and municipal water with the Columbia River as its source. A hypothetical "maximum" individual has been assigned assumed dietary habits which are identical to those used in the 1966 through 1969 annual reports (*1–3,17*). The consumption rates of most foods for this hypothetical "maximum" individual were compiled from intake rates described in published dietary surveys and have been documented separately in detail (*18,19*).

The composite doses estimated for this "maximum" individual for 1970 are shown graphically in figure 7 and summarized in table 16. Major decreases from the 1969 values were noted for all estimated organ doses.

1970 dose estimates for bone, whole body, and GI tract of the "maximum" individual continued to be predominantly from external exposure while fishing plus the consumption of Columbia River fish. The relative contributions from other pathways were greater than in the past, as radioactivity in the river declined with successive reactor shutdowns. The "maximum" individual thyroid dose declined even more sharply in 1970 due to the reduction in radioiodines released to the river in reactor effluents. The composite annual doses for 1967 through 1970 are shown in table 17.

The "average" Richland resident

Estimates of average consumption rates of several food items were obtained for Richland adults from analysis of dietary questionnaires completed by plant employees. The program and the data have been discussed in previous reports (*3,19*). Not only are quantities consumed smaller

Table 16. Summary of annual radiation doses[a] in the Hanford environs, 1970

Organ	Dose standard (mrem)	Calculated dose (mrem)	Percent of standard
Maximum individual:			
Bone	1 500	94	6
Whole body	500	12	2
GI tract	1 500	27	2
Thyroid (infant)	1 500	30	2
Average Richland resident:			
Bone	500	9	2
Whole body	170	2	1
GI tract	500	12	2
Thyroid (infant)	500	8	2

[a] Doses from fallout and natural background not included.

Table 17. Comparable dose estimates for maximum individual and average Richland resident, 1967–1970[a]

Organ	Percent of standard				Dose standard (mrem/yr)
	1967	1968	1969	1970	
Maximum individual:					
Bone	26	17	9	6	1 500
Whole body	6	5	4	2	500
GI tract	5	4	3	2	1 500
Thyroid (infant)	6	7	4	2	1 500
Average Richland resident:					
Bone	5	3	3	2	500
Whole body	3	2	2	1	170
GI tract	6	5	4	2	500
Thyroid (infant)	8	8	5	2	500

[a] Not including contributions from fallout or natural background radiation.

than for the hypothetical "maximum" individual, sources of food, milk, and water based on the survey data indicate much greater dependence on commercial sources.

In computing doses for the "average" Richland resident, the assumed sources were Richland drinking water (with average concentrations adjusted for radioactive decay and dilution), Columbia River fish (with the average species composition of fish ingested by the "maximum" individual, but a much smaller quantity), an average species mix of gamebirds, and average amounts of milk, meat, and produce from local stores.

Because no significant contribution from Hanford operations to the ambient radiation levels in Richland has been discerned in the past, the external dose to the "average" Richland resident was assumed to result only from recreational use of the Columbia River. An

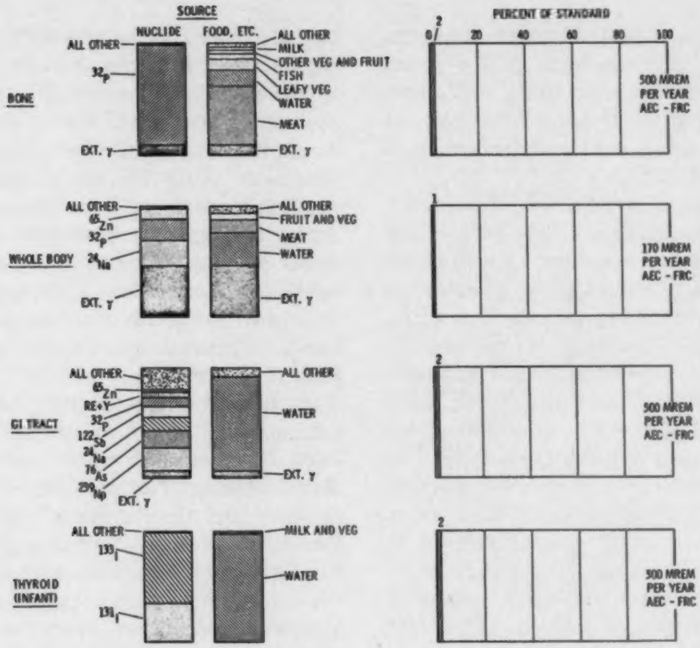


Figure 8. Estimated doses to the "average" Richland resident, 1970

estimated annual dose increment of 2 mrem from immersion in the river and activities along the shoreline was included in the GI tract, whole body, and bone doses. No such increment was included in the thyroid dose, calculated for an infant, because of the limited use of the river by this age group.

The composite doses estimated for the "average" Richland resident for 1970 are displayed in figure 8 and summarized in table 15. All 1970 doses estimated for the "average" Richland resident, like those for the "maximum" individual, decreased significantly with reduced radioactivity in the river and associated pathways.

For the "average" Richland resident, consumption of drinking water was by far the most important source of radiation dose. Because of the broad spectrum of radionuclides in the drinking water, however, no one radionuclide predominated as a dose contributor to all organs.

The trend of exposure to the "average" Richland resident over the 1967–1970 period also is shown in table 17.

Conclusions

The 1970 Hanford environmental surveillance program indicated continued compliance of the Hanford contractors and their operations with applicable environmental standards. Most of the environmental radiation dose for people living in the Hanford environs was due to natural sources and regional fallout rather than to Hanford operations. Although much reduced from previous years, the largest source of radioactivity released to man's immediate environment from Hanford continued to be reactor cooling water discharged to the Columbia River.

The basic standards for evaluating the adequacy of radiological control at Hanford are taken to be radiation doses to specified population groups, as given in AEC Manual, Chapter 0524 (*20*).

The surveillance program included sampling and analysis on a routine basis of river water, municipal drinking water, groundwater, air, milk, foodstuffs, fish, shellfish, and gamebirds.

Measurements were made of external gamma exposure rates at land stations, in the river, over the river surface, and along the river shoreline. Contamination surveys were made at selected plots and along public highways adjacent to the Hanford site.

Shutdown in February 1970, of KW reactor, one of the two remaining single-pass, river water-cooled production reactors, as well as an extended shutdown of all reactors, greatly reduced the major remaining source of population exposure from Hanford operations. In 1970, average river concentrations of radionuclides were less than 3 percent of the AEC standards, and transport rates of radionuclides in the river were much reduced from 1969. The radionuclide showing the highest average percentage of its AEC standard in treated water at the Richland water plant was sodium–24 at 2.1 percent. Reductions from 1969 values were seen in radionuclide concentrations in Columbia River fish, shoreline radiation levels, and direct radiation measurements of the river.

Groundwater contamination originating in the chemical separations areas showed no appreciable advance toward the Columbia River. Tritium in groundwater around N reactor area may have contributed to an apparent small increase measured in river tritium concentration between Vernita and Richland, but the average downstream concentration from all sources, including weapons test and natural formation, was less than .05 percent of the AEC standard.

Airborne radioactivity measurements continued to show the occasional presence of fallout from weapons testing. Particulate radioactivity concentrations around the site perimeter, however, were essentially the same as at more distant locations, indicating a lack of contribution from Hanford sources. Land-based gamma radiation measurements showed the same pattern, with a small increase from 1969 to 1970. Radioiodines were not detected in air or milk samples except during a fallout occurrence.

Unusually high concentrations of phosphorus–32 were found in 4 of 15 ducks collected at 2 trenches receiving undiluted reactor cooling water. Immediate consumption of a normal meal of the duck with the highest phosphorus–32 concentration in muscle, 0.14 μCi/g, could theoretically have resulted in a radiation dose to skeletal bone of about 6 rem, four times the applicable standard. However, based on hundreds of ducks collected during years of routine sampling along the river and nearer public hunting areas, radionuclide concentrations in ducks resident for extended periods on open water around the plant facilities are not representative of those birds likely to be taken and consumed by the public. Corrective action was taken to prevent any further access by waterfowl to the trenches.

As in past years, annual radiation doses resulting from Hanford operations were calculated for the bone, whole body, GI tract, and thyroid for both a hypothetical "maximum" individual and the "average" Richland resident. During 1970, calculated doses of Hanford origin were all much less than one-tenth of the applicable dose standards, reflecting a general and significant decrease from comparable 1969 values.

The hypothetical "maximum" individual postulated to receive the largest plausible dose from Hanford sources is assumed to have the following sources of exposure:

200 meals of fish caught downstream from the reactors,

500 hours on the river shoreline catching the fish,

milk, meat, and produce in season from farms irrigated with river water, and

drinking water from a municipal water supply taken from the river.

For 1970, the annual skeletal bone dose for this "maximum" individual was calculated as 94 mrem, or 6 percent of the applicable standard of 1 500 mrem. Doses to both the GI tract and the whole body were estimated to be about 2 percent of the respective standards.

For thyroid dose estimates, an infant with a 2-gram thyroid, consuming milk and some vegetables from river-irrigated farms, was considered the "maximum" individual. Dietary habits postulated for such an infant could have resulted in an annual dose to the thyroid of about 2 percent of the standard of 1 500 mrem.

The "average" Richland resident also is defined as an adult for estimation of bone, whole body, and GI tract doses, and as an infant for estimation of thyroid dose. The dietary and recreational habits of the "average" Richland resident have been determined from local surveys. The small radiation doses received by this population group in 1970 from Hanford operations continued to originate in most part from radionuclides discharged to the Columbia River in reactor cooling water and taken into the Richland municipal supply. For dose estimation, radionuclide concentrations measured at the Richland water treatment plant were adjusted for dilution and radioactive decay in the water distribution system. For 1970, the calculated GI tract and bone doses were 2 percent of the standard of 500 mrem per year for this population group. The whole body dose was estimated to be about 1 percent of the standard of 170 mrem per year. The thyroid dose to the average Richland infant was calculated to be about 2 percent of the standard of 500 mrem per year.

REFERENCES

(1) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1969, BNWL-1505 and BNWL-1505 APP. C. B. Wilson and T. H. Essig, editors, Battelle-Northwest, Richland, Wash. (November 1970).

(2) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1968, BNWL-1341 APP. C. B. Wilson, editor, Battelle-Northwest, Richland, Wash. (May 1970).

(3) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1967, BNWL-983 and BNWL-983 APP. C. W. Wooldridge, editor, Battelle-Northwest, Richland, Wash. (March 1969).

(4) U.S. DEPARTMENT OF THE INTERIOR, U.S. GEOLOGICAL SURVEY. Weekly runoff reports—Pacific Northwest water resources (1970). Northwest Water Resources Data Center, Portland, Oreg. (1970).

(5) ESSIG, T. H. Radiological status of the groundwater beneath the Hanford project, July-December 1970, BNWL-1613. Battelle-Northwest, Richland, Wash. (September 1971).

(6) SOLDAT, J. K. A statistical study of the habits of fishermen utilizing the Columbia River below Hanford, BNWL-SA-1451. Battelle-Northwest, Richland, Wash. (1968).

(7) PUBLIC HEALTH SERVICE. National shellfish sanitation program, manual of operations, PHS Publication No. 33. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1965).

(8) INTERNATIONAL COMMISSION OF RADIOLOGICAL PROTECTION. Report of ICRP Committee II on permissible dose for internal radiation, with bibliography for biological, mathematical, and physical data, ICRP Publication No. 2. Pergamon Press, Ltd., Oxford, London (1959).

(9) SOLDAT, J. K. Gamebird data. Battelle-Northwest, Richland, Wash. (unpublished 1969).

(10) HONSTEAD, J. F. Recreational use of the Columbia River—evaluation of environmental exposure, BNWL-CC-2299. Battelle-Northwest, Richland, Wash. (October 1969).

(11) PHILIPP. L. L. and E. M. SHEEN. Aerial and ground gamma survey monitors, BNWL-62. Battelle-Northwest, Richland, Wash. (May 1965).

(12) BUREAU OF RADIOLOGICAL HEALTH. Milk surveillance, December 1969. Radiol Health Data Rep 11:187-197 (April 1970).

(13) U.S. ATOMIC ENERGY COMMISSION. Summary of available data on the strontium-90 content of foods and of total diets in the United States, HASL-90, Health and Safety Laboratory, AEC, New York, N.Y. (August 1960).

(14) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection, ICRP Publication 6, amended 1959 and revised 1962. Pergamon Press, N.Y. (1964)

(15) FEDERAL RADIATION COUNCIL. Protective action guides for strontium-89 and cesium-137, background material for the development of radiation protection standards, staff report number 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20460 (1965).

(16) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 2, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(17) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1966, BNWL-439 and BNWL-439 APP. T. H. Essig and J. K. Soldat, editors, Battelle-Northwest, Richland, Wash. (June 1967).

(18) WILSON, R. H. and T. H. ESSIG. Criteria used to estimate radiation dose received by persons living in the vicinity of Hanford: Interim Report, BNWL-706. Battelle-Northwest, Richland, Wash. (July 1968).

(19) ESSIG, T. H. and J. P. CORLEY. Criteria used to estimate radiation doses received by persons living in the vicinity of Hanford: Interim Report No. 2, BNWL-1019. Battelle-Northwest, Richland, Wash. (April 1969).

(20) U.S. ATOMIC ENERGY COMMISSION. AEC manual standards for radiation protection, Chapter 0524. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (February 1969).

Reported Nuclear Detonations, March 1974

(Includes seismic signals presumably from foreign nuclear detonations)

There were no reported nuclear detonations for the United States for March 1974 and no recorded seismic signals for this month.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

MICROWAVE HAZARD MEASUREMENTS NEAR VARIOUS AIRCRAFT RADARS. *Richard A. Tell* and *John C. Nelson. Radiation Data and Reports, Vol. 15, April 1974, pp. 161–179.*

In order to determine the potential for exposure of individuals when in the vicinity of aircraft radar units when aircraft are on the ground, the Electromagnetic Radiation Analysis Branch monitored four radar units that were typical of radars used by commercial aircraft. Two of the units were surveyed at a radar simulation laboratory and the other units were surveyed while in their operating positions in aircraft.

The survey determined that the radar beams from navigational and weather radar units in commercial aircraft rotate in either a sector-scanned or 360 degree rotation at approximately 15 r/min. The radar beams emanated from the aircraft above 6 feet from the ground. It was determined that power density exposures of 10 mW/cm can occur from 8 to 18 feet from the antenna of an aircraft radar unit.

No radiation levels in excess of 0.2 mW/cm^2 existed in the aircraft cockpits.

KEYWORDS: Aircraft, microwave, radar, radiation.

ORDER BLANK FOR RD&R

To: Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

Please enter my subscription for Radiation Data and Reports. I am enclosing Money Order ☐ Check ☐ for this subscription. ($13.45 a year; $3.40 additional for foreign mailing.)

Please address RD&R as follows. ______________________________

____

____

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C., 1974
For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Subscription price $13.45 a year, $3.40 additional for foreign mailing.
Price for a single copy of this issue is $1.20.

April 1974

GUIDE FOR AUTHORS

The editorial staff invites reports and technical notes containing information related to radiological health. Proposed reports and notes should contain data and interpretations. All accepted manuscripts are subject to copy editing with approval of the author. The author is responsible for all statements made in his work.

Manuscripts are received with the understanding that other identical manuscripts are not under simultaneous consideration nor have appeared in any other publication.

The mission of *Radiation Data and Reports* is stated on the title page. It is suggested that authors read it for orientation of subject matter.

Submission of manuscripts

Send original and one legible copy of the paper, typed doubled-spaced on 8½ by 11-inch white bond with 1-inch margins.

Submitted manuscripts should be sent to Editor, Radiation Data and Reports, HM-561, EPA, Office of Radiation Programs, Waterside Mall East, Room 615, Washington, D.C. 20460.

Preparation of manuscripts

The Government Printing Office style manual is used as a general guide in the preparation of all copy for *Radiation Data and Reports*. In addition, past issues of *Radiation Data and Reports* would serve as a suitable guide in preparing manuscripts.

Titles, authors: Titles should be concise and informative enough to facilitate indexing. Names of authors should appear on the third line below the manuscript title. Affiliation of each author should be given by a brief footnote including titles, professional connections at the time of writing, present affiliation if different, and present address.

Abstracts: Manuscripts should include a 100- to 150-word abstract which is a factual (not descriptive) summary of the work. It should clearly and concisely state the purpose of the investigation, methods, results and conclusions. Findings that can be stated clearly and simply should be given rather than to state that results were obtained.

A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

Introductory paragraph: The purpose of the investigation should be stated as early as possible in the introductory paragraph.

Methods: For analytical, statistical, and theoretical methods that have appeared in published literature a general description with references to sources is sufficient. New methods should be described clearly and concisely with emphasis on new features. Both old and new methods, materials, and equipment, should be described clearly enough so that limitations of measurements and calculations will be clear to the readers. Errors associated with analytical measurements and related calculations should be given either as general estimates in the text or for specific data in appropriate tables or graphs whenever possible.

Illustrations: Glossy photographic prints or original illustrations suitable for reproduction which help enhance the understanding of the text should be included with the manuscript. Graphic materials should be of sufficient size so that lettering will be legible after reduction to printed page size (8½ by 6½ inches).

All illustrations should be numbered and each legend should be typed double-spaced on a separate sheet of paper. Legends should be brief and understandable without reference to text. The following information should be typed on a gummed label or adhesive strip and affixed to the back of each illustration: figure number, legend, and title of manuscript or name of senior author.

Tables: Tables should be self-explanatory and should supplement, not duplicate, the text. Each table should be typed on a separate sheet, double-spaced. All tables must be numbered consecutively beginning with 1, and each must have a title.

Equations: All equations must be typewritten, preferably containing symbols which are defined immediately below the equation. The definition of symbols should include the units of each term. Special symbols, such as Greek letters, may be printed carefully in the proper size, and exponents and subscripts should be clearly positioned. Mathematical notations should be simple, avoiding when feasible such complexities as fractions with fractions, subscripts with subscripts, etc.

Symbols and units: The use of internationally accepted units of measurements is preferred. A brief list of symbols and units commonly used in *Radiation Data and Reports* is given on the inside front cover of every issue and examples of most other matters of preferred usage may be found by examining recent issues. Isotope mass numbers are placed at the upper left of elements in long series of formulas, *e.g.*, ^{137}Cs; however, elements are spelled out in text and tables, with isotopes of the elements having a hyphen between element name and mass number; *e.g.*, strontium-90.

References: References should be typed on a separate sheet of paper.

Personal communications and unpublished data should not be included in the list of references. The following minimum data for each reference should be typed double-spaced: names of all authors in caps, complete title of article cited, name of journal abbreviated according to *Index Medicus*, volume number, first and last page numbers, month or week of issue, and year of publication. They should be arranged according to the order in which they are cited in the text, and not alphabetically. All references must be numbered consecutively.

Reprints

Contributors are ordinarily provided with 50 courtesy copies of the articles in the form of reprints. In cases of multiple authorship, additional copies will be provided for coauthors upon request.

U.S. ENVIRONMENTAL
PROTECTION AGENCY
OFFICE OF RADIATION PROGRAMS
WASHINGTON, D.C. 20460

OFFICIAL BUSINESS

U.S.MAIL

POSTAGE AND FEES PAID
U.S. ENVIRONMENTAL PROTECTION
AGENCY
EPA-335

Please CHECK if you do not desire to continue receiving this publication ☐; or, if a change of address is needed ☐ (indicate change, including zip code); tear off this cover and return to the above address.

RHD UNIVM300UH 48106D 1
UNIV MICROFILMS SERIALS SEC
300 NO ZEEB RD
ANN ARBOR MI 48106